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ON THE GEOLOGICAL FORMATIONS OF LAKE SUPERIOR.*

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III. Upper Copper-bearing Series.

The name of the Upper Copper-bearing Rocks of Lake Superior was given to this series by Sir W. E. Logan, to distinguish it from the Huronian or Lower Copper-bearing Rocks. The geographical and geological position, lower altitude, regular bedding, and peculiar lithological character of these Upper Rocks cause them to be easily recognised and readily distinguished from the Huronian. They have been separated into an upper and lower group, the latter of which seems, however, to be confined to the north-west parts of the lake. Along its eastern shore, between Sault St. Marie and Michipicoten, there are frequently found, betwixt the water and the high Huronian or Laurentian hills, narrow strips or patches of the rocks of the upper group, which often jut out as small islands into the lake, and doubtless extend out great distances beneath its waters. Such limited strips of these rocks are found, for instance, skirting the base of Gros Cap, along the south shore of Bachewahnung Bay and at Cape Gargantua. But besides these and much more important for the study of the upper group of the Upper Copper-bearing series, there are occasional extensive developments of its rocks, many thousand feet in thickness, such as at Cape Mamainse, Michipicoten Island, and Point Keweenaw

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on the south shore. These rocks have been generally described in the Geology of Canada as sandstones, conglomerates, stratified traps and amygdaloids. In referring to them more minutely, the following rock-varieties may be distinguished as belonging to the upper group of the series:—

Granular Melaphyre.—A large number of the rocks of this series which have hitherto been described as traps and greenstones, belong to this species. The simplest variety of it is seen at the north-west end of Michipicoten Island, and consists of two minerals only, a felspar and a greenish black mineral. The felspar is the principal constituent, possesses a red, almost pink, colour, which it loses on ignition, and being readily fusible and but slightly decomposed by acids, is most probably oligoclase, or closely allied to that species in composition. The dark coloured mineral is easily fusible and has the appearance of augite. Some of it appears soft and decomposed, and has most probably been converted into delessite. These two minerals are combined into a small grained, distinctly compound rock, which does not effervesce with acids, and whose red colour is visible at a considerable distance. It is very seldom however that this rock is observed with such a bright colour, or with constituents so distinctly separated. Much more frequently the felspar has a dark reddish-brown colour, and the grains of augite or delessite have a very indistinct contour. This is the case with some of the melaphyres of Mamainse and Gros Cap. When the brown coloured felspar predominates, and the augitic or chloritic constituent becomes scarcer and even more indistinct, rock-varieties are developed belonging to the species Porphyrite, hereafter to be described. When, on the other hand, the dark greenish constituent gains the upper hand, and is recognisable as consisting almost exclusively of delessite, it gives rise to the variety of melaphyre next described.

Delessitic Melaphyre.—This rock has a greenish-gray colour, and consists of a granular mixture of felspar and delessite, with small portions of magnetite and undecomposed augite. In some instances mica is also found as a constituent. The delessite, besides occurring in small grains, often forms larger rounded particles and amygdules, without however imparting to the rock a very marked amygdaloidal structure. The rocks enclosing the cupriferous beds of the Pewabic and Quincy Mines, and that from the Quincy adit are examples of this variety, and have already been described by me in this journal.* The delessite which enters so largely into their composition can scarcely have been one of the original constituents, and has probably resulted from the gradual alteration of augite, since authenticated instances are on record of the conversion of that mineral into delessite and green-earth. The specific gravity of these rocks varies from 2.83 to 2.89. When ignited they lose 1.32 to 3.09 per cent. of their weight, the powder changing from light greenish-grey to a light brown colour. Digested with hydrochloric acid from 32.44 to 35.72 per cent. of bases are removed from them, the greater part of which belongs to the chloritic constituent. While the variety of melaphyre first above described is seldom found with amygdaloidal structure, the delessitic melaphyres are exceedingly prone to be developed as amygdaloids. In this case the rock contains amygdules of small size but very numerous, and they are either filled with delessite alone, or are lined with a coating or rind of that mineral, in which latter case calcspar generally fills out the centre of the cavity. Quartz or agate is comparatively rare in amygdaloids the matrix of which is delessitic melaphyre.

Compact Melaphyre.—When the small grained melaphyres above described become so fine-grained as to render the recognition of their constituents impossible, there results the fine-grained traps which are so numerous on the south-west coast of Mamainse and on Michipicoten Island. These rocks vary from reddish, bluish, greenish, or greyish black, to decided black in colour, and possess not unfrequently conchoidal fracture and resinous lustre. Their specific gravities vary from 2.67 to 2.898, and they fuse before the blowpipe to glasses of black or brownish black colour. Occasionally their material becomes less homogeneous, and presents the appearance of an intimate mixture of reddish grey and green coloured specks, which may perhaps represent partially developed constituents. They exhibit various phenomena as regards divisional joints. Some possess a rudely columnar structure, others have planes of separation forming various angles with the plane of bedding, several shew a tendency to separate into flags, while a few instances are observable of curved shaly separation, (*Krummschaalige Absonderung*). Transitions can frequently be traced from these compact melaphyres to others approaching in

* Vol. iii., Second Series, p. 2.

character to porphyrite. For instance, to the west of the entrance to the harbour on the south side of Michipicoten Island, there is found, forming part of a bed of undoubted compact melaphyre, a rock of a greenish-grey colour, with conchoidal fracture. It had a specific gravity of 2.589, and could only be glazed at the edges before the blowpipe. To the east of the same harbour entrance, another rock occurs intermediate in character betwixt compact melaphyre and porphyrite. It is black, impalpable, with imperfectly conchoidal fracture. It bears some resemblance to pitchstone, but differs from that rock in its specific gravity, which is 2.774, and in being readibly fusible to a black glass. It possesses a slightly resinous lustre, and contains an occasional crystal of colourless triclinic felspar. It exhibits planes of separation at right angles, or nearly so with the inclination of the bed, and agate veins are observable, which seem to accompany the divisional joints. This latter phenomenon is also seen in some of the beds of compact melaphyre, and in one of these, curved joints are visible, standing at right angles to the plane of bedding and filled out with calcspar. Brecciated quartz veins occasionally permeate these rocks, and agatic geodes are very frequent among them. The latter are sometimes so frequent as to form amygdaloids, but they are much larger, and never so numerous as are the cavities in the amygdaloids of which delessitic melaphyre is the matrix. There is further this peculiarity with the amygdules of the compact melaphyres, that they contain little or no delessite, agate occupying its place, with occasionally calcspar filling the centre of the geode.

Tufaceous Melaphyre.—Interstratified with the rocks above described, and much more frequently associating with, and graduating into the delessitic melaphyres than the other varieties, there are occasionally found beds of comparatively soft, dark brown, porous rock, with almost earthy fracture and seldom destitute of amydaloidal structure. These frequently carry metallic copper, and constitute the 'ash beds' so extensively worked in the mines of the south shore. Although they are generally of a dark brown or chocolate colour, as in the case of the 'Pewabic lode,' there are rocks of this species which are bluish-brown and green coloured. The matrix is generally fusible, and in places impregnated with grains of metallic copper, sometimes of a very minute size. The larger grains of the metal are frequently found in the amygdules, either alone or accompanied by green-earth, calcspar, quartz, delessite, laumontite, and prehnite. Besides the rounded grains or 'shot copper' of the amygdules, these rocks often contain huge masses of metallic copper, with which small quantities of native silver are associated. Large irregular patches and veins of calcspar, and smaller masses of epidote are frequently met with in these tufaceous melaphyres.

Porphyrite.—The transitions, which are frequently observable on the south side of Michipicoten Island, from compact melaphyre to porphyrite have been referred to above. Undoubted porphyrite is to be found at the south-west corner of the Island. It possesses a fine-grained greenish red matrix, containing small flesh-coloured crystals of felspar, some of which have striated cleavage planes. The specific gravity of the rock is 2.619, and the matrix is fusible at the edges. In the upper part of the bed the matrix of the rock becomes coarser grained, shewing distinctly felspar and a darker coloured mineral as constituents, with the small felspathic crystals still scattered through it. The felspar predominates in the matrix and determines the colour of the rock, which is dark red. Its specific gravity is 2.626, and it is fusible, although not readily, before the blow-pipe. It separates into blocks, with very decided divisional planes, but of no regular form. Similar rocks are found at the south-east corner of the Island, where also rocks resembling pitchstone and pitchstone porphyry are extensively developed. The black shining impalpable trap, which has the appearance of pitchstone, has a specific gravity of 2.573. It is fusible to a brown glass, and sometimes contains small colourless felspar crystals. Where these accumulate, there results the rock resembling pitchstone porphyry. The crystals in this rock are frequently recognisable as triclinic. The matrix is fusible to a brown blebby glass, and the specific gravity of the rock as a whole is 2.631 to 2.678. Since the specific gravity of the rock in which no crystals occur is lower than that usually ascribed to melaphyre, and since it is greater than that of true pitchstone, it would appear reasonable to class both these rocks with the porphyrites, or with these porphyries which contain no quartz, to which they probably bear the same relation as true pitchstones bear to felsitic or quartzose porphyries.

Melaphyre Breccia.—Among the newest of the beds of compact melaphyre, developed on Michipicoten Island, there are sometimes observable beds of a breccia consisting of fragments of dark brown melaphyre, cemented together by a reddish-brown trappean sand. Occasionally the fragments appear rounded, and present more of the character of a conglomerate. Similar rocks are seen in the Point Keweenaw district.

Porphyritic Conglomerate.--At the south-west corner of Michipicoten Island there is visible a conglomerate bed, the boulders of which consist principally of porphyrite, in which a few minute felspar crystals are discernible. Some of the boulders are granitic, and occasionally pebbles occur consisting of or containing agate. These are enclosed in a matrix consisting of coarse-grained and red-coloured porphyritic or trappean debris. *In the upper part* of the Mamainse group similar conglomerates are found, but in one instance the matrix seems to consist of the same crystalline material as the boulders and fragments, and is very firmly cemented to these. The most interesting example of this rock is that of the Albany and Boston mine, near Portage Lake. Here the matrix of coarse-grained porphyritic sand is accompanied by calcspar, and in some places fine metallic copper.* Other porphyritic conglomerates occur to the south of Portage Lake, some of the boulders of which consist of quartzose porphyry, and the matrix of some of which contains quartz as well as calcspar.

Felsite-tuff.—Overlying the Albany aud Boston conglomerate a bed of so-called 'fluckan' occurs, which is a fine-grained, dark-red shaly rock, in which pieces of a greenish blue colour are sometimes seen. Both substances are fusible before the blow-pipe, and contain occasionally small grains and flakes of copper.

Polygenous Conglomerate.—This name is applied by Naumann and Zirkel to those fragmentary rocks whose boulders consist of two or more different rocks. Conglomerates of this nature are especially frequent among the inferior rocks of the Mamainse group, and among those of Keweenaw Point. The boulders of these Mamainse conglomerates are chiefly of granite, gneiss, quartzite, greenstone, and slate, and some of the newer beds contain boulders of melaphyre and amygdaloid in abundance. The matrix is generally a dark red sandstone.

Sandstone.—Among the melaphyres and conglomerates of Mamainse and Point Keweenaw an occasional stratum of sandstone is found of the same character as that which forms the matrix of the polygenous conglomerates.

The manner in which the rocks above described are associated with each other, is much more regular than the architecture of

* This Journal, Vol. iii., Second Series, p. 9.

the Laurentian and Huronian rocks. They are regularly interstratified with each other, and even among the melaphyres and porphyrites distinct bedding is observable. They do not seem to have been disturbed to such a degree as to occasion the formation of anticlinal and synclinal folds, and in each of the principal areas of distribution a tolerably persistent strike and dip can be observed.

The general strike of the rocks of the Mamainse group is N. 20° to 50° W., and the dip 20° to 45° south-westward. They are beautifully exposed along the west coast of Mamainse, and the highest strata of the group form the south-west extremity of the cape. The lower part of the group consists of granular and delessitic melaphyres, polygenous conglomerates and sandstone. In the upper part compact melaphyres and porphyritic conglomerates predominate. The total thickness of the group, according to an approximative measurement, is 16,208 feet, of which the conglomerates occupy 2,138 feet. The succession of the beds along the coast is quite regular; but on attempting to follow them inland, they are found to thin out and disappear, while others take their places. This is especially the case with the conglomerates. Were the beds continuous throughout, the section above given ought to be repeated on the south coast, and round to Anse-aux-Crêpes. But there, although some of the melaphyre beds have the same strike and dip as on the west coast, there is not the same regularity, nor the same plentiful development of conglomerates. There are moreover evidences of great disturbances and of a conflict between the rock of some of the igneous beds and a sandstone, which here appears in highly contorted and sometimes vertical strata. On coming round the south coast of Mamainse, from Anse-aux-Crêpes, strata of sandstone are observed very much disturbed and dipping inland. As near as it can be ascertained, their strike is about N. 85° W., dip 25° to 40° northward. The sandstone is red coloured, and contains streaks and spots of a cream coloured felspathic substance, which also forms bands crossing the stratification. Many thin cracks filled with calcspar also traverse the beds. The same sandstone continues for about a hundred and forty yards further to the west, becoming still more disturbed, and containing between its layers the felspathic substance. The strike, where the beds are at all regular, is N. 10° W., and dip 52° eastward. Further west it changes to N. 52° E., with dip vertical, and in places 75° S. W. Here the sandstone becomes utterly broken up into a breccia, which has pieces from one inch to a foot in diameter invariably angular, and a matrix consisting of the white felspathic substance above mentioned, with occasionally calcspar. Further westward the measures are concealed for two hundred yards; then strata of bluish-grey calcareous sandstone are exposed, striking N. 40° E., and dipping 75° S. E. From this point for three hundred yards further north-westward, disturbed sandstone occupies the coast where the measures are not concealed. It is followed by a breccia similar to that already mentioned, with angular fragments of sandstone, and then by beds of trappean rocks, striking N. 75° W., and dipping 40° S. W. Rocks of this nature occupy the coast, where not concealed, for one and a half miles further north-westward. Here sandstone again becomes visible, in strata almost vertical, but nevertheless much bent. It is covered by a breccia consisting of sandstone fragments with a trappean matrix, and this again is surmounted by regular trap. In many places there would seem to be the clearest evidence that the trap lies unconformably upon the upturned and contorted edges of the sandstone. Besides the breccia above mentioned, other rocks of a peculiar nature are found at the junction of the sandstone and trap. One of these is indistinguishable from quartzose perphyry, and another seems to consist of fragments of trap bound together by this same quartzose perphyry. There are good grounds for supposing that the latter rock is the product of the action of the more basic trap upon the sandstone, and results from the igneous amalgamation of the two rocks last named. These confused rocks occupy about a quarter of a mile of the coast. To the north-westward, although the sandstones occasionally protrude, they become much less frequent, while the overlying melaphyres become much more regular, and gradually assume the same strike and dip as the strata on the west coast. The hills to the north of Anse-aux-Crêpes consist of the same beds of melaphyre and conglomerate as were observed on the west coast, with similar strike and dip.

The eruptive origin of the melaphyres and traps of this group is evidenced not only by their crystalline character, and by some of their relations in contact with undoubted sedimentary rocks, but also by their occurring as intrusive masses in the gneiss of Point-aux-Mines, and in the granitoid gneiss of Chippewa Falls. At the latter place the melaphyre is in the form of a dyke, and at Point-aux-Mines it is seen to form a dome-shaped mass, completely surrounded by gnessiod rocks. Furthermore, the lower members of the Mamainse series are intersected by numerous dykes, consisting of compact melaphyre. In some of them, the constituents of that rock are distinguishable, but most of them are almost impalpable, vary from a reddish-brown to a dark green colour, and frequently exhibit at their sides bands of slightly different colours, which run parallel with the side-walls of the dyke.

The average strike of the Upper Copper-bearing rocks of Michipicoten Island is N. 68° E., and the dip 25° south-eastward. An approximative estimate of their thickness is as follows:—

Granular, delessitic and compact melaphyres, and conglomerates.................	10,000 feet.
Compact melaphyres with agate amygdules.	4,500 "
Resinous traps, porphyrites and breccias...	4,000 "
	18,500 feet.

If we compare the rocks of Michipicoten Island with those of Mamainse, it would appear that the inferior rocks of the latter group do not come to the surface at Michipicoten Island, and that the higher rocks of the Michipicoten group have not been developed at Mamainse, or lie beneath the waters of the lake to the south-west of the promontory. It would therefore appear just, in estimating the thickness of the Upper Copper-bearing rocks of the eastern part of Lake Superior, to add to the Mamainse series the above mentioned 4000 feet of resinous traps or porphyrites, which would make the whole thickness at least 20,000 feet. The rocks of the west and south shores of Michipicoten Island present the most regular appearance, and it might be expected that those of the south shore would, from their strike and dip, repeat themselves on the east side. But, as in the case of Mamainse, such an expectation is disappointed. On examining the rocks of the east shore, the upper beds, consisting of the porphyrites above mentioned, seem regular enough, but beneath these come brecciated melaphyre, delessitic melaphyre cut by a porphyritic rock, and others in which the evidences of bedding are very indistinct. Among these rocks the two following may be particularised as occuring in large masses. The first has an impalpable flesh-red or reddish-grey matrix, wherein occur numerous grains of dark grey quartz, and also light-coloured soft particles, which seem liable to removal by atmospheric agencies, giving the rock where this has taken place a porous appearance.

It also contains light red and ash-grey crystalline grains of felspar, and others which appear earthy and decomposed. The matrix is fusible, in fine splinters only, to a white enamel. The rock has an uneven fracture, a specific gravity of 2.493, and ; probably a porphyritic quartz-trachyte. The other rock, which occupies a very considerable area, partakes more of the character of felsitic porphyry, although the felspar crystals are very often indistinct. It contains, besides these, numerous grains of greyish quartz, sometimes one-eighth of an inch in diameter, and a fine-grained, dark red, difficultly fusible, matrix. The specific gravities of three different specimens were found to be 2.548, 2.579, and 2.583. The bedding of the rock, if it possesses any, is very obscure; but it shews in places a tendency to separate into flags. It has a very rough uneven fracture, and is probably also quartzose trachyte. At the north-east corner of the Island it seems to overlie, unconformably, beds of trap, which here assume something like the ordinary strike and dip, viz., N. 72° E., dip 25° S. E.

The islands which lie opposite the mouth of the harbour on the south shore are composed of a peculiar rock, which is nowhere visible on the main island. It consists of a reddish-brown impalpable matrix, with a hardness but slightly inferior to that of orthoclase, in which minute spots of a soft yellowish-white material are discernible. There are also lighter flesh-coloured grains observable, which seem to be incipient felspar crystals. The matrix is difficultly fusible to a colourless blebby glass, and the specific gravity of the whole rock, where freshly broken, is 2.469. A piece slightly bleached to a greyish-white, from its adjoining a crack in the rock, gave a specific gravity of 2.477. Some parts of it exhibit a slightly porous structure, but this was not the case with either of the pieces whose specific gravity were determined. The rock has a very uneven fracture, and is probably trachytic phonolite. The occurrence of these trachytic rocks on Michipicoten Island is very interesting, for they are the only ones of the region which have in other countries been found in connection with undoubted volcanoes.

The general strike of the strata of the rocks of Point Keweenaw, at least in the neighbourhood of Portage Lake is N. 30° to 40° E., and the dip 55° to 70° north-westward. The melaphyres predominate, although polygenous and porphyritic conglomerates are also frequent. The copper-bearing tufaceous melaphyres seem to be more plentiful here than in the other areas, or at least the mines to which they give rise are more extensively worked.

At the other points in the east shore of the lake, where rocks of the character of melaphyre have been observed, the area occupied by them is very limited, and confined to narrow strips of beach and rocky ground, between the lake and the much more elevated Laurentian or Huronian rocks. In the most westerly cove on the south shore of Bachewahnung Bay, red sandstone is observed striking N. 12° W., and dipping 15° south-westward. It is interstratified with conglomerate, the b lders of which are principally of quartzite, dark green slate and red-jasper conglomerate, which have doubtless been derived from the Huronian hills in the rear. They range in diameter from one to twelve and even eighteen inches. The matrix is generally red sandstone, but the interstices are sometimes filled out with quartz. A short distance along the shore to the north-east exposures occur of a reddish-brown melaphyre tuff, containing amygdules of calcspar and quartz, the matrix of which is very soft and decomposed. The beds appear to strike N. 8° E., and dip 25° to 29° westward. They would therefore seem to be conformable with the sandstone and conglomerate. Further north-eastward the rock becomes more compact, of a reddish-green colour, and exhibits curves of igneous flow. The geodès become much less frequent and consist almost exclusively of agate. The next rock to the north-east is a light red sandstone, striking N. 65° W., and dipping 35° to 40° N. E. Its contact with the trap is not visible, but its dip is such as to lead to the supposition that it has been disturbed by that rock. There is a great thickness of this sandstone exposed here, in strata frequently vertical, striking generally east and west, or to the north of west, and exhibiting dips varying from 35° N. to 57° S., and at least two anticlinal axes. From what has been stated here and also concerning the south shore of Mamainse, it would appear that there is evidence of the existence of a sandstone of greater age than the bedded melaphyres and conglomerates, and it would appear not unreasonable to suppose that it belongs to what has been called the Lower group of the Upper Copper-bearing series.

The trap rocks which surround the south-west base of Gros Cap, although comparatively seldom amygdaloidal, are readily distinguished as melaphyres. They are sometimes coarse-grained, consisting of reddish-grey felspar, soft dark-green iron-chlorite (delessite), and occasional spots of yellowish-green epidote. From this they graduate into finer-grained varieties, but they very seldom become impalpable, or their constituents altogether indistinguishable. Sandstone was not observed in contact with the traps, but a large mass of quartzose porphyry is seen at a short distance from the shore.

Another large development of traps and sandstones occurs to the north of Pointe-aux-Mines, where an occasional bed of tufaceous melaphyre is also found.

Besides the rocks above described, there are found on the low ground betwixt Goulais and Bachewahnung Bays, betwixt the latter and Pancake Bay, and on many of the islands of the east shore, large areas of red sandstone, almost horizontal, which are supposed to be the continuation of that occurring at Sault St. Marie, and usually called the St. Peter Sandstone. The true relations of this rock to those of the upper group of the Upper Copper-bearing series have not yet been made out. It closely resembles, in lithological character, the sandstone described above as occurring in almost vertical strata on the south shore of Bachewahnung Bay. The disturbance of the latter is reasonably attributable to the neighbouring melaphyres, in which case the sandstone would be the earlier rock. On the other hand, as Sir W. E. Logan observes, "the contrast between the general moderate dips of these sand- "stones and the higher inclination of the igneous strata at "Gargantua, Mamainse, and Gros Cap, combined with the fact "that the sandstones always keep to the lake side of these, while "none of the many dykes which cut the trappean strata, it is "believed, are known to intersect the sandstones (at any rate on "the Canadian side of the lake), seem to support the suspicion "that the sandstones may overlie unconformably those rocks "which, associated with the trap, constitute the copper-bearing "series."* The following facts are confirmatory of this view. In the bay immediately south of Point-aux-Mines, where the Mamainse series adjoins the Laurentian rocks, the lowest member of the former is unconformably overlaid by thin bedded bluish and yellowish-grey sandstones, striking N. 50° E., and dipping 15° north-westward. The lowest layer is a conglomerate, with granitic and trappean boulders, and a bluish, fine-grained and slaty matrix.

* Geology of Canada, p. 85.

It is about six feet thick, and is followed by thirty feet of the thin bedded sandstones, some parts of which might yield good flagstones. Some of the surfaces of these are very distinctly ripple-marked. Above these come thin, shaly, rapidly disintegrating layers, in which are found spheroidal concretions from five to ten inches in diameter. It is not possible to ascertain the total thickness of these sandstones, since they descend beneath the level of the lake. They are similar in lithological character to the sandstones which occur on the north side of Point-aux-Mines. Although there is no doubt that these sandstones unconformably overlie the melaphyre series, still their lithological characters are very different from those of the horizontal red sandstone above referred to. The latter is evenly small-grained, is coloured red by iron oxide, and contains here and there small pieces of red shale, which have evidently furnished the colouring matter. It frequently consists of evenly bedded red and yellowish-grey layers, and exhibits sometimes the phenomenon named by Naumann, discordant parallel-structure, and by Lyell, diagonal or cross stratification.

In enquiring next as to what geological formation in Europe most closely resembles the Upper Copper-bearing series of Lake Superior, the opinion expressed by Delesse ought not to be lost sight of, viz., that the constituent minerals have the same meaning and importance for eruptive rocks which organic remains have for those of sedimentary origin. Therefore, where the palæontological evidence does not entirely contradict it, that derived from lithological resemblance ought to be allowed its full weight. The melaphyres of the upper rocks being interbedded with conglomerates and sandstones, the age of the latter may be ascertained approximatively by enquiring under what circumstances and during what period the melaphyres of Europe were developed. Upon this point Naumann thus expresses himself: "With regard "to the eruption-epochs of the melaphyres, there appears, indeed, "to have been many of them, but the most occur in the period "of the Rothliegende, or in the first half of the Permian formation, and all are probably more recent than the Carboniferous "system. This applies at least to the melaphyres on the south "side of the Hundsrück, to those of the Thuringian Forest, of the "neighbourhood of the Hartz, of Lower Silesia, Bohemia, and "Saxony. Many of these melaphyres were deposited soon "after the commencement, others towards the end, of the

" Rothliegende period, and generally the latter, in many countries, shews a decided coincidence, both as regards time and space, with the formation of the melaphyres." Zirkel, in his recent work on "Petrographie," gives a description of the melaphyre deposits of Germany, of which the following is a translation: "In districts which are older than the Carboniferous formation melaphyre rocks are but seldom found. The melaphyres of the southern Hundsrück and of the Pfalz, whose stratigraphical relations are better known than their mineralogical composition, appear in the Carboniferous system or the lower Rothliegende. This melaphyre region extends from Düppenweiler to Kreuznach, a distance of twelve miles, with a breadth between St. Wendel, Birkenfeld, Kirn, and Grumbach of several miles. Very few irregular masses are known, but, on the other hand, numerous veins have been observed with thicknesses varying from four to sixty feet. They possess mostly a vertical dip, cut sharply the Carboniferous strata, and often extend on their strike considerable distances. The mass of the vein frequently encloses fragments of the side rock, slate-clay or sandstone. But most frequently in this region, the melaphyres present themselves in the form of beds, which are of very variable dimensions, (often only five to ten feet, sometimes two hundred feet thick,) and lie, for the most part, evenly inserted between the strata of the Carboniferous system. Some of these can be traced for a distance of two miles. Besides these a melaphyre layer appears in this region, extending over many square miles. It is superimposed upon the upper strata of the Carboniferous system, and upon it rest the Conglomerates, sandstones and slate-clays of the Rothliegende. This great covering of melaphyre is at its edges accompanied by melaphyre-tuffs, which are in many places developed as melaphyre-amygdaloids. In very few instances only has it been observed that these melaphyres have exerted altering influences upon the side-rock. Within the limits of the Rothliegende melaphyres are very frequent. According to Naumann the melaphyre of Ilfeld in the Hartz, must be regarded as a thick layer bedded into the Rothliegende. It nevertheless in places lies immediately over the Carboniferous system, on account of its extending beyond the edges of the lower strata of the Rothliegende. Naumann also mentions a mass of melaphyre which in Tyrathal covers the junction of the Greywacke with the Rothliegende, and in its

" further extension overlies also the latter formation. The " melaphyre-amygdaloid of Planitz, near Zwickau in Saxony, " forms also a covering regularly inserted into the Rothliegende, " above its inferior strata. On the western declivity of the " Oberhohndorfer Hill, near Zwickau, the melaphyre which here " contains numerous green-earth and calcspar amygdules, shews an " interesting intercalation with the brownish-red slate-clays of the " Rothliegende, irregular lumps and patches of which being as it " were kneaded into the mass of the melaphyre. The melaphyric " rock of the Johann-Friedrich and Zabenstadter Adit, in Mansfeld, " is evenly interstratified in the Rothliegende. G. Leonhard " mentions that in the Rothliegende of the neighbourhood of " Darmstadt, at Gœtzenhain and Urberach, the melaphyre forms " distinct outbursts of considerable size in the form of domes " (*Kuppen*,) which consist in the centre of solid melaphyre, and " towards the periphery of amygdaloidal rocks, and shews in " places both flagstone-like and columnar separation. In Silesia " the melaphyres appear in two places: in the country between " Lœwenberg and Læhn, where they, according to the investi- " gations of Beyrich, occur in several courses, striking from " north-west to south-east, intersecting the Rothliegende, and " in still more extended measure at the edge of the great " bay opening towards south-east in the Grauwacke at Landeshut, " in which the carboniferous formation and the Rothliegende " have been deposited, and in which they form, according to Zobel " and Von Carnal, a range extending from Schatzlar to Neurode. " In north-eastern Bohemia, according to Emil Porth, and " Jokély, malaphyres are found as numerous, and sometimes very " thick layers, in the Rothliegende. Jokély describes, in the " district of Jicin, five beds of melaphyre in various parts of the " Rothliegende, which exhibit very distinctly observable strati- " graphical relations. They prove to be, for the most part, true " melaphyre streams, which have flown like lavas, and in visible " connection with undoubted vein-like outbursts. According to " Porth, the neighbourhood of the melaphyre veins is frequently, " for great distances round, a field of melaphyric ash and " scoriæ."*

From these quotations it is plain that, in Europe, melaphyres only made their appearance during the Carboniferous and Permian

* Zirkel; Petrographie. Vol. ii., p. 71.

periods, and especially characterised the latter. The occurrence of porphyritic conglomerates in Germany is similarly limited. On this point Zirkel says: "As porphyritic eruptions principally fall "in the period of the Rothliegende, so the whole of the clastic "rocks of the porphyry family stand in close connection with the "deposition of its strata, to which they have also contributed a "considerable amount of material. For instance, coarse porphy-"ritic conglomerates form members of the Upper Rothliegende "in the Oschatz-Frohburg basin, in the Döhlen basin, at Wieser-"städt in the Hartz, and in the north-western part of Thüringia. "At Baden, in the Black Forest, the deepest strata of the "Rothliegende consist of porphyritic breccia and the middle "strata of conglomerates." * Even polygenous conglomerates, such as those above-mentioned, are especially frequent among the carboniferous and permian strata of Europe. Naumann thus briefly characterises the Rothliegende of Germany, which he considers as equivalent to the English lower New Red Sandstone and the French *grès rouge*: "The Rothliegende appears in so "many of the countries of Germany, and in such great thickness, "that, in its mode of development there, we recognise the normal "type of this remarkable sandstone formation. The pigment of "the sandstone, consisting principally of iron-oxide, the frequent "occurrence of conglomerates, the often repeated change in the "size of grain of its rocks, the association with porphyries and "melaphyres, the very frequent layers of claystones and porphy-"ritic conglomerates, the great poverty, and often complete "absence of organic remains,—all these are characters by which "the Rothliegende is distinguished as quite a peculiar sandstone "formation."† That not one of the peculiarities here emphasised by Naumann are absent from the upper group of the Upper Copper-bearing rocks of Lake Superior, will be evident to any one who has observed them or carefully gone through the description above given. It therefore becomes a matter of much importance, and deserving of the most careful study, to ascertain whether this resemblance is a mere coincidence, or whether there is reason for supposing that any part of these Upper Copper-bearing rocks are of Permian age.

* Zirkel; Petrographie. Vol. ii., p. 529.

† Naumann; Lehrbuch der Geognosie. Vol. ii., p. 584.

BRITISH ASSOCIATION.

SCIENTIFIC EDUCATION IN SCHOOLS.

Mr. Griffith read the report which had been prepared by the Committee on this subject, the members of which were:—The general officers of the Association, the Trustees, the Rev. F. W. Farrar, M.A., F.R.S., the Rev. T. N. Hutchinson, M.A., Professor Huxley, F.R.S., Mr. Payne, Professor Tyndall, F.R.S., and Mr. J. M. Wilson, M.A.

1. A demand for the introduction of science into the modern system of education has increased so steadily during the last few years, and has received the approval of so many men of the highest eminence in every rank and profession, and especially of those who have made the theory and practice of education their study, that it is impossible to doubt the existence of a general, and even national, desire to facilitate the acquisition of some scientific knowledge by boys at our public and other schools.

2. We point out that there is already a *general* recognition of science as an element in liberal education. It is encouraged to a greater or less degree by the English, Scottish, and Irish Universities; it is recognized as an optional study by the College of Preceptors; it forms one of the subjects in the local examinations of Oxford and Cambridge; and it has even been partially introduced into several public schools. We have added an appendix containing information on some of these points. But the means at present used in our schools and universities for making this teaching effective, are, in our opinion, capable of great improvement.

3. That general education in schools ought to include some training in science is an opinion that has been strongly urged on the following grounds:—

1. As providing the best discipline in the observation and collection of facts, in the combination of inductive with deductive reasoning, and in accuracy both of thought and language.

2. Because it is found in practice to remedy some of the defects of ordinary school education. Many boys on whom the ordinary school studies produce very slight effect, are stimulated and improved by instruction in science; and it is found to be a most valuable element in the education of those who show special aptitude for literary culture.

3. Because the methods and results of science have so profoundly affected all the philosophical thought of the age, that an educated man is under a very great disadvantage if he is unacquainted with them.

4. Because very great intellectual pleasure is derived in after life from even a moderate acquaintance with science.

5. On grounds of practical utility as materially affecting the present position and future progress of civilization.

This opinion is fully supported by the popular judgment. All who have much to do with the parents of boys in the upper classes of life are aware that, as a rule, they value education in science on some or all of the grounds above stated.

4. There are difficulties in the way of introducing science into schools; and we shall make some remarks on them. They will be found, we believe, to be by no means insuperable. First among these difficulties, is the necessary increase of expense. For if science is to be taught, at least one additional master must be appointed; and it will be necessary in some cases to provide him with additional school-rooms, and a fund for the purchase of apparatus. It is obvious that the money which will be requisite for both the initial and current expenses must in general be obtained by increasing the school fees. This difficulty is a real but not a fatal one. In a wealthy country like England, a slight increase in the cost of education will not be allowed (in cases where it is unavoidable) to stand in the way of what is generally looked upon as an important educational reform; and parents will not be unwilling to pay a small additional fee if they are satisfied that the instruction in science is to be made a reality.

Another ground of hesitation is the fear that the teaching of science will injure the teaching in classics. But we do not think that there need be the slightest apprehension that any one of the valuable results of a classical education will be diminished by the introduction of science. It is a very general opinion, in which school-masters heartily concur, that much more knowledge and intellectual vigour might be obtained by most boys, during the many years they spend at school, than what they do as a matter of fact obtain. It should, we think, be frankly acknowledged, and, indeed, few are found who deny it, that an exclusively classical education, however well it may operate in the case of the very few who distinguish themselves in its curriculum, fails deplorably for the majority of minds. As a general rule, the small proportion of boys who leave our Schools for the Universities consists undeniably of those who have advanced furthest in classical studies, and judging the existing system of education by these boys alone, we have to confess that it frequently ends in astonishing ignorance. This ignorance, often previously acknowledged and deplored, has been dwelt on with much emphasis, and brought into great prominence by the recent Royal Commission for Inquiry into our public schools. We need not fear that we shall do great damage by endeavouring to improve a system which has not been found to yield satisfactory results. And we believe, further, that the philological abilities of the very few who succeed in attaining to a satisfactory knowledge of classics will be rather stimulated than impeded by a more expansive training.

Lastly, it may be objected that an undue strain will be put upon the minds of boys by the introduction of the proposed subjects. We would reply that the same objections were made, and in some schools are still made, to the introduction of mathemathics and modern languages, and are found by general experience to have been untenable. A change of studies, involving the play of a new set of faculties, often produces a sense of positive relief; and at a time when it is thought necessary to devote to games so large a proportion of a boy's available time, the danger of a general over pressure to the intellectual powers is very small, while any such danger in individual cases can always be obviated by special remissions. We do not wish to advocate any addition to the hours of work in schools where it is believed that they are already as numerous as is desirable; but in such schools some hours a week could still be given up to science by a curtailment of the vastly prepondere.ıt time at present devoted to classical studies, and especially to Greek and Latin composition.

5. To the selection of the subjects that ought to be included in a programme of scientific instruction in public schools we have given our best attention, and we would make the following remarks on the principles by which we have been guided in the selection that we shall propose.

There is an important distinction between scientific *information* and scientific *training;* in other words, between general literary acquaintance with scientific facts, and the knowledge of methods that may be gained by studying the facts at first hand under the guidance of a competent teacher. Both of these are valuable; it is very desirable, for example, that boys should have some general information about the ordinary phenomena of nature, such as the simple facts of astronomy, of geology, of physical geography, and of elementary physiology. On the other hand, the scientific habit of mind, which is the principal benefit resulting from scientific training, and which is of incalculable value whatever be the *pursuits of after life, can better be attained by a thorough* knowledge of the facts and principles of one science, than by a general acquaintance with what has been said or written about many. Both of these should co-exist, we think, at any school which professes to offer the highest liberal education; and at *every* school it will be easy to provide at least for giving some scientific information.

1. The subjects that we recommend for scientific *information* *as distinguished from training, should comprehend a general* description of the solar system; of the form and physical geography of the earth, and of such natural phenomena as tides, currents, winds, and the causes that influence climate; of the broad facts of geology; of elementary natural history, with especial reference to the useful plants and animals; and of the rudiments of physiology. This is a kind of information which requires less preparation on the part of the teacher; and its effectiveness will depend on his knowledge, clearness, method, and sympathy with his pupils. Nothing will be gained by circumscribing these subjects by any general syllabus; they may safely be left to the discretion of the masters who teach them.

2. And for scientific *training* we are decidedly of opinion that the subjects which have paramount claims are experimental physics, elementary chemistry, and botany.

i. The science of experimental physics deals with subjects which come within the range of everybody's experience. It embraces the phenomena and laws of light, heat, sound, electricity and magnetism, the elements of mechanics, and the mechanical properties of liquids and gases. The thorough knowledge of these subjects includes the practical mastery of the apparatus employed in their investigation. The study of experimental physics involves the observation and collation of facts, and the discovery and application of principles. It is both inductive and deductive. It exercises the attention and the memory, but makes both of them subservient to an intellectual discipline higher than either. The teacher can so present his facts as to make them suggest the principles which underlie them, while, once in possession of the principle, the learner may be stimulated to deduce from it results which lie beyond the bounds of his experience. The subsequent verification of his deduction by experiment never fails to excite his interest and awaken his delight. The effects obtained in the class-room will be made the key to the explanation of natural phenomena,—of thunder and lightning, of rain and snow, of dew and hoar-frost, of winds and waves, of atmospheric refraction and reflection, of the rainbow and the mirage, of meteorites, of terrestrial magnetism, of the pleasure and buoyancy of water and of air. Thus the knowledge acquired by the study of experimental physics is, of itself, of the highest value, while the acquisition of that knowledge brings into healthful and vigorous play every faculty of the learner's mind. Not only are natural phenomena made the objects of intelligent observation, but they furnish material for them to wrestle with and overcome; the growth of intellectual strength being the sure concomitant of the enjoyment of intellectual victory. We do not entertain a doubt that the competent teacher who loves his subject and can sympathise with his pupils, will find in experimental physics a store of knowledge of the most fascinating kind, and an instrument of mental training of exceeding power.

ii. Chemistry is remarkable for the comprehensive character of the training which it affords. Not only does it exercise the memory and the reasoning powers, but it also teaches the student to gather by his own experiments and observations the facts upon which to reason.

It affords a corrective of each of the two extremes against which real educators of youth are constantly struggling. For on the one hand, it leads even sluggish or uncultivated minds from simple and interesting observations to general ideas and conclusions, and gives them a taste of intellectual enjoyment and a desire for learning. On the other hand, it checks over-confidence in mere reasoning, and shows the way in which valid extensions of our ideas grow out of a series of more and more rational and accurate observations of external nature.

It must not, however, be supposed that all so-called teaching of chemistry produces results of this kind. Young men do occasionally come up to public examinations with a literary acquaintance with special facts and even principles of chemistry, sufficient to enable them to describe those facts from some one point of view, and to enunciate the principles in fluent language, and yet who know nothing of the real meaning of the phrases which they have learnt. Such mere literary acquaintance with scientific facts is in chemistry an incalculable evil to the student if he be allowed to mistake it for science.

Whether the student is to learn much or little of chemistry, his very first lessons must be samples of the science. He must see the chief phenomena which are described to him; so that the words of each description may afterwards call up in his mind an image of the thing. He must make simple experiments, and learn to describe accurately what he has done, and what he has observed. He must learn to use the knowledge which he has acquired before proceeding to the acquisition of more; and he must rise gradually from well examined facts to general laws and theories.

Among the commonest non-metallic elements and their simplest compounds, the teacher in a school will find abundant scope for his chief exertions.

iii. Botany has also strong claims to be regarded as a subject for scientific training. It has been introduced into the regular school course at Rugby, (where it is the first branch of natural science which is studied); and the voluntary pursuit of it is encouraged at Harrow, and at some other schools with satisfactory results. It only requires observation, attention, and the acquisition of some new words; but it also evolves the powers of comparison and the colligation of facts in a remarkable degree. Of all sciences it seems to offer the greatest facilities for observation in the fields and gardens; and to this must be added the fact that boys, from their familiarity with fruits, trees, and flowers, start with a considerable general knowledge of botanical facts. It admits therefore pre-eminently of being taught in the true scientific method. The teaching of science is made really valuable by training the learner's mind to examine into his present knowledge, to arrange and criticise it, and to look for additional information. The science must be begun where it touches his past experience, and this experience must be converted into scientific knowledge. The discretion of the teacher will best determine the range of botany at which it is desirable to aim.

6. The modes of giving instruction in the subjects which we have recommended are reducible to two:—

1. A compulsory system of instruction may be adopted, similar to that which exists at Rugby, where science has now for nearly three years been introduced on precisely the same footing as

mathematics and modern languages, and is necessarily taught to all boys.

2. A voluntary system may be encouraged, as has been done for many years' at Harrow, where scientific instruction on such subjects as have been enumerated above, is now given in a systematic series of lectures, on which the attendance of all boys who are interested in them is entirely optional.

Of these systems it is impossible not to feel that the compulsory system is the most complete and satisfactory. The experience of different schools will indicate how it may best be adopted, and what modifications of it may be made to suit the different school arrangements. It will often be very desirable to supplement it by the voluntary system, to enable the boys of higher scientific ability to study those parts of the course of experimental physics which will rarely, if ever, be included in the compulsory school system. Lectures may also be occasionally given by some non-resident lecturer, with a view of stimulating the attention and interest of the boys. We add appendices containing details of these two systems as worked at Rugby and Harrow, and we believe that a combination of the two would leave little or nothing to be desired.

The thorough teaching of the physical sciences at schools, will not, however, be possible, unless there is a general improvement in the knowledge of arithmetic. At present many boys of thirteen and fourteen, are sent to the public schools, almost totally ignorant of the elements of arithmetic, and in such cases they gain only the most limited and meagre knowledge of it; and the great majority enter ill taught. It is a serious and lasting injury to boys so to neglect arithmetic in their early education; it arises partly from the desire of the masters of preparatory schools to send up their boys fitted to take a good place in the classical school, and from the indifference of the public schools themselves to the evil that has resulted.

7. With a view to the furtherance of this scheme, we make the following suggestions:—

1. That in all schools natural science be one of the subjects to be taught, and that in every public school at least one natural science master be appointed for the purpose.

2. That at least three hours a week be devoted to such scientific instruction.

3. That natural science should be placed on an equal footing

with mathematics and modern languages in affecting promotions, and in winning honours and prizes.

4. That some knowledge in arithmetic should be required for admission into all public schools.

5. That the universities and colleges be invited to assist in the introduction of scientific education, by making natural science a subject of examination, either at matriculation, or at an early period of a university career.

6. That the importance of appointing lecturers in science, and offering entrance scholarships, exhibitions, and fellowships, *for the encouragement of scientific attainments*, be represented to the authorities of the colleges.

With reference to the last two recommendations, we would observe that without the co-operation of the universities, science can never be effectively introduced into school education. Although not more than 35 per cent., *even of the boys at our great public* schools, proceed to the university, and at the majority of schools a still smaller proportion, yet the curriculum of a public school course is almost exclusively prepared with reference to the requirements of the universities and the rewards for proficiency that they offer. No more decisive proof could be furnished of the fact that the universities and colleges have it in their power to alter and improve the whole higher education of England.

APPENDIX A.

1. Oxford.

The Natural Science School at Oxford was established in the year 1853. By recent changes, the university allows those who have gained a first, second, or third class in this school to graduate without passing the classical school, provided they have obtained honours, or have passed in three books at least at the second classical examination—viz., moderations (which is usually passed in the second year of residence); honours in this school are thus placed on an equality with classical honours. The first classical examination, "responsions," is generally passed in the first term of residence. Arithmetic and two books of Euclid, or algebra up to simple equations, are a necessary part of this examination.

The university offers ample opportunities for the study of physics, chemistry, physiology, and other branches of natural science. At present, only a few of the colleges have lecturers on this subject; while for classics and mathematices every college professes to have an adequate staff of teachers. At Christ Church, however, a very complete chemical laboratory has been lately opened.

A junior studentship at Christ Church and a demyship at Magdalen College, tenable for five years, are, by the statutes of those colleges awarded annually for profiency in natural science. A scholarship, tenable for three years, lately founded by Miss Brackenbury, at Balliol College, for the promotion of the study of natural science, will be given away every two years. With the exception of Merton College, where a scholarship is to be shortly given for proficiency in natural science, no college has hitherto assigned any scholarships to natural sciences. The number of scholarships at the colleges is stated to be about 400, varying in annual value from £100 to £60. With these should be reckoned college exhibitions, to the number of at least 220, which range in annual value from £145 to £20, and exhibitions awarded at school, many of which are of considerable value.

The two Burdett-Coutts geological scholarships, tenable for two years, and of the annual value of £75, are open to all members of the university who have passed the examination for the B.A. degree, and have not exceeded the 27th term from their matriculation. Every year a fellowship of £200 a year, tenable for three years (half of which time must be spent on the continent) on Dr. Radcliffe's foundation, is at present competed for by candidates, who, having taken a first class in the school of natural science, propose to enter the medical profession.

At Christ Church, two of the senior studentships (fellowships) are awarded for proficiency in natural science. At the examination for one of these, chemistry is the principal subject, and for the other physiology.

At Magdalen College, it is provided that, for twenty years from the year 1857, every fifth fellowship is assigned to mathematics and physical science alternately. In the statutes of this, and of every college in Oxford (except Corpus, Exeter, and Lincoln) the following clause occurs:—"The system of examinations shall always be such as shall render fellowships accessible, from time to time, to excellence in every branch of knowledge for the time being recognized in the schools of the university." This clause, so far as it relates to the study of natural science, has been acted on only by Queen's College and at Merton College, where a natural science fellowship will be filled up during the course of the present year.

At Pembroke College, one of the two Sheppard fellows must proceed to the degree of Bachelor and Doctor of Medicine in the university. At the late election to this fellowship, natural science was the principal subject in the examination. The number of college fellowships in Oxford is at present about 400.

2. Cambridge.

It is important to distinguish between the university and the colleges at Cambridge as at Oxford.

There is a natural science tripos in which the university examines in the whole range of natural sciences, and grants honors precisely in the same manner as in classics or mathematics.

The university also recognizes the natural sciences as an alternative subject for the ordinary degree. As the regulations on this point are comparatively recent, it will be well to state them here.

A student who intends to take an ordinary degree without taking honours has to pass three examinations during his course of three years,—the first, or previous examination, after a year's residence, in Paley, Latin, Greek, Euclid, and arithmetic, and one of the gospels in greek ; the second, or general examination, towards the end of his second year, in the Acts of the Apostles in Greek, Latin, Greek, Latin prose composition, algebra, and elementary mechanics, and the third, or special examination, at the end of his third year, in one of the following five subjects:— 1. Theology; 2. Moral Science; 3. Law; 4. Natural Science; 5. Mechanism and applied Science.

In the natural science examination, a choice is given of chemistry, geology, botany, and zoology.

There are only five colleges in Cambridge that take any notice of natural science—viz., Kings, Caius, Sidney, Sussex, St. John's, and Downing. At Kings, two exhibitions have been given away partly for proficiency in this subject ; but there are no lectures, and it is doubtful whether similar exhibitions will be given in future. At Caius there is a medical lecturer and one scholarship given away annually for anatomy and physiology. At Sidney Sussex two scholarships annually are given away for mathematics and natural science ; and a prize of £20 for scientific knowledge.

There is also a laboratory for the use of students. At St. John's there is a chemical lecturer and laboratory; and though at this college there is no sort of examination in natural science either for scholarships or fellowships, it is believed distinction in the subject may be taken into account in both elections. Downing was founded with "especial reference to the studies of law and medicine;" there is a lecturer here in medicine and natural science, and in the scholarship examinations one paper in these subjects; no scholarship is appropriated to them, but they are allowed equal weight with other subjects in the choice of candidates. It is believed that the same principle will govern the election to fellowships in this college, though no fellowship has yet been given for honours in natural science. We believe that, owing to the new university regulations (mentioned above), the authorities of Trinity College have determined to appoint a lecturer in natural science; the matter is under deliberation in other colleges, and it is not improbable that the same considerations will induce them to follow this example.

It must always be remembered that the practice is rare in Cambridge of appropriating fellowships and scholarships to special subjects. At present public opinion in the University does not reckon scientific distinction as on a par with mathematical or classical; hence, the progress of the subject seems enclosed in this inevitable circle—the ablest men do not study natural science because no rewards are given for it, and no rewards are given for it because the ablest men do not study it. But it may be hoped that the disinterested zeal of teachers and learners will rapidly break through this circle; in that case the subject may be placed on a satisfactory footing withont any express legislative provision.

3. The University of London.

At the University of London the claims of science to form a part of every liberal education have long been recognized. At the matriculation examination the student is required to show that he possesses at least a popular knowledge of the following subjects:—

a. In *Mechanics*.—The composition and resolution of forces; the mechanical powers; a definition of the centre of gravity; and the general laws of motion.

b. In *Hydrostatics*, *Hyrdaulics*, and *Pneumatics*.—The pressure of liquids and gases; specific gravity; and the principles of the action of the barometer, the siphon, the common pump and forcing pump, and the air-pump.

c. In *Acoustics*.—The nature of sound.

d. In *Optics*.—The laws of refraction and reflection, and the formation of images by simple lenses.

e. In *Chemistry*.—The phenomena and laws of heat; the chemistry of the non-metallic elements; general nature of acids, gases, &c.; constitution of the atmosphere; composition of water, &c.

At the examination for the degree of B.A. a more extensive knowledge of these subjects is required, and the candidate is further examined in the following branches of science:—

f. *Astronomy*.—Principal phenomena depending on the motion of the earth round the sun, and on its rotation about its own axis; general description of the solar system, and explanation of lunar and solar eclipses.

g. *Animal Physiology*.—The properties of the elementary animal textures; the principles of animal mechanics; the processes of digestion, absorption, assimilation; the general plan of circulation in the great divisions of the animal kingdom; the mechanism of respiration; the structure and actions of the nervous system; and the organs of sense.

Besides the degree examination there is also an examination for *honours* in mathematics and natural philosophy, in which, of course, a much wider range of scientific knowledge is required.

We would venture to remark that, if a similar elementary acquaintance with the general principles of sciences were required for matriculation at Oxford and Cambridge, it is certain that they would at once become a subject of regular teaching in all our great public schools.

There are also two specially scientific degrees, a Bachelor of Science, and a Doctor of Science. For the B. S. there are two examinations of a general but highly scientific character. The degree of D. S. can only be obtained after the expiration of two years subsequent to the taking the degree of B. S. The candidate is allowed to select one *principal subject*, and to prove his thorough practical knowledge thereof, as well as a general acquaintance with other subsidiary subjects.

4. The College of Preceptors.

In the diploma examinations at the College of Preceptors, one branch of science—viz., either chemistry, natural history, or physiology—is required as a *necessary* subject for the diploma of *Fellow*. In the examinations for the lower diploma of Associate or Licentiate some branch of science *may* be taken up by candidates at their own option. The council recently decided to offer a prize of three guineas half-yearly for the candidate who showed most proficiency in science, and who at the same time obtained a second class in the other subjects.

In the examinations of pupils of schools, natural philosophy, chemistry, and natural history are optional subjects only, and are not *required* for a certificate for the three classes. Two prizes are given to those candidates who obtain the highest number of marks in these subjects at the half-yearly examinations; and it is an interesting fact that last year, out of a total of 651 candidates, 100 brought up natural history, and 36 brought up chemistry as subjects for examination. Two additional prizes were consequently awarded.

5. The French Schools.

In France the "Lycées" correspond most nearly to our public schools, and for many years science has formed a distinct part of their regular curriculum. A strong impulse to the introduction of scientific teaching into French schools was given by Napoleon I., and since that time we believe that no French school has wholly neglected this branch of education. The amount of time given to these subjects appears to average two hours in every week.

The primary education is that which is given to all alike, whatever may be their future destination in life, up to the age of eleven or twelve years. After this period there is "bifurcation" in the studies of boys. Those who are intended for business or for practical professions lay aside Greek and Latin, and enter on a course of "special secondary instruction." In this course, mechanics, cosmography, physics, chemistry, zoology, botany, and geology occupy a large space; and the authorized official programmes of these studies are very full, and are drawn up with the greatest care. The remarks and arguments of the Minister of Public Instruction (Mons. Duruy) and others in the "Programmes officiels, etc., de l'enseignement secondaire spécial," are extremely valuable and suggestive; and we recommend the syllabuses of the various subjects, which have received the sanction of the French government, as likely to afford material assistance to english teachers in determining the range and limits of those scientific studies at which, in any special system of instruction, they may practically aim. The "Enseignement secondaire spécial" might very safely be taken as a model of what it is desirable to teach in the "modern departments" which are now attached to some of our great schools.

The boys who are destined to enter the learned professions continue a classical course, in which, however, much less time is devoted to classical composition than is the case in our public schools. Nor is science by any means neglected in this course, which is intended to cover a period of three years. Besides the "*elementary division,*" *there are five great classes in these schools*, viz., a grammar division, an upper division, a philosophy class, and classes for elementary and special mathematics.

In the grammar division there is a systematic instruction on the physical geography of the globe.

In the second class of the upper division the boys begin to be taught the elements of zoology, botany, and geology in accordance with the ministerial programmes; and in the rhetoric class descriptive cosmography (which seems to be nearly co-extensive with the German *Erkunde*) forms the subject of a certain number of weekly lessons.

In the class of philosophy, the young students are initiated into the elementary notions of physics (including weight, heat, electricity, and magnetism, acoustics, and optics) and of chemistry, in which, at this stage, the teaching is confined to "general conceptions on air, water, oxidation, combustion, the conditions and effects of chemical action, and on the forces which result from it."

In the classes of elementary and special mathematics, this course of scientific training is very considerably extended; and if the authorized programmes constitute any real measure of the teaching, it is clear that no boy could pass through these classes without a far more considerable amount of knowledge in the most important branches of science than is at present attainable in any English Public School.

6. The German Schools.

In Germany the schools, which are analogous to public schools in England, are the *Gymnasia*, where boys are prepared for the universities, and the *Bürgerschulen* or *Realschulen*, which were established for the most part about thirty years ago, for the purpose of affording a complete education to those who go into active life as soon as they leave school. An account of the Prussian Gymnasia and Realschulen may be seen in the Public School Commission Report, Appendix G; further information may be obtained in "Das höhere Schulwesen in Preussen," by Dr. Wiese, published under the sanction of the Minister of Public Instruction in Prussia, and in the programmes issued annually by the school authorities throughout Germany.

At the Gymnasia natural science is not taught to any great extent. According to the Prussian official instructions, in the highest class two hours, and in the next class one hour a week are allotted to the study of physics. In the lower classes, two hours a week are devoted to natural history, *i. e.*, botany and zoology.

The results of the present training in natural science at the Gymnasia are considered by many eminent university professors in Germany to be unsatisfactory, owing to the insufficient time allotted to it.

In the Realschulen about six hours a week are given to physics and chemistry in the two highest classes, and two or three hours a week to natural history in the other classes. In these schools all the classes devote five or six hours a week to mathematics, and no Greek is learnt. In Prussia there were in 1864 above one hundred of these schools.

APPENDIX B.

On the Natural Science Teaching at Rugby.

Before the summer of 1864, a boy, on entering Rugby, might signify his wish to learn either modern languages or natural science; the lessons were given at the same time, and therefore excluded one another. If he chose natural science, he paid an entrance fee of £1 1s., which went to an apparatus fund, and £5 5s. annually to the lecturer. Out of the whole school, numbering from 450 to 500, about one-tenth generally were in the natural science classes.

The changes proposed by the Commissioners were as follows:—That natural science should no longer be an alternative with modern languages, but that all boys should learn some branch of it; that there should be two principal branches—one consisting of chemistry and physics, the other of physiology and natural history, animal and vegetable—and that the classes in natural science should be entirely independent of the general divisions of the school, so that boys might be arranged for this study exclusively according to their proficiency in it.

Since, owing to circumstances which it would be tedious to detail, it was impossible to adopt literally the proposals of the Commissioners, a system was devised which must be considered as the system of the Commissioners in spirit, adapted to meet the exigencies of the case.

The general arrangement is this—that new boys shall learn botany their first year, mechanics their second, geology their third, and chemistry their fourth.

In carrying out this general plan certain difficulties occur, which are met by special arrangements depending on the peculiarities of the school system. We need not here enter upon these details, because it would be impossible to explain them simply, and because any complications which occur in one school would differ widely from those which are likely to arise in another.

Next, as to the nature of the teaching.

In botany the instruction is given partly by lectures and partly from Oliver's Botany. Flowers are dissected and examined by every boy, and their parts recognized and compared in different plants and then named. No technical terms are given till a familiarity with the organ to be named or described has given rise to their want. The terms which express the cohesion and adhesion of the parts are gradually acquired until the floral schedule, as highly recommended by Henslow and Oliver, can be readily worked. Fruit, seed, inflorescence, the forms of leaf, stem, root, are then treated, the principal facts of vegetable physiology illustrated, and the principle of classification into natural orders explained, for the arrangement of which Bentham's "Handbook of the British Flora" is used. Contrary to all previous expectation, when this subject was first introduced it became at once both popular and effective among the boys.

The lectures are illustrated by Henslow's nine diagrams, and by a large and excellent collection of paintings and diagrams made by the lecturers and their friends, and by botanical collections made for use in lectures. When the year's course is over, such boys as show a special taste are invited to take botanical walks with the principal lecturer, to refer to the school herbarium, and are stimulated by prizes for advanced knowledge and for dried collections, both local and general.

In mechanics, the lecturer is the senior natural science master. The lectures include experimental investigations into the mechanical powers, with numerous examples worked by the boys; into the elements of mechanism, conversion of motion, the steam engine, the equilibrium of roofs, bridges, strength of material, &c. They are illustrated by a large collection of models, and are very effective and popular lectures.

The lectures in geology are undertaken by another master. This subject is only temporarily introduced, on account of the want of another experimental school. When this is built, the third year's course will be some part of experimental physics, for which there already exists at Rugby a fair amount of apparatus. It is very desirable that boys should obtain some knowledge of geology, but it is not so well fitted for school teaching as some of the other subjects, on several grounds. Perhaps a larger proportion of boys are interested in the subject than in any other; but the subject pre-supposes more knowledge and experience than most boys possess, and their work has a tendency to become either superficial, or undigested knowledge derived from books alone. The lectures include the easier part of Lyell's Principles, *i. e.*, the causes of change now in operation on the earth; next, an account of the phenomena observable in the crust of the earth, stratification and its disturbances, and the construction of maps and sections; and lastly, the history of the stratified rocks and of life on the earth. These lectures are illustrated by a fair geological collection, which has been much increased of late, and by a good collection of diagrams and views to illustrate geological phenomena.

For chemistry, the lecturer has a convenient lecture-room, and a small but well-fitted laboratory; and he takes his classes through the non-metallic and metallic elements: the lectures are fully illustrated by experiments. Boys, whose parents wish them to study chemistry more completely, can go through a complete course of practical analysis in the laboratory, by becoming private pupils of the teacher. At present twenty-one boys are studying analysis.

This being the matter of the teaching, it remains to say a few words on the manner. This is nearly the same in all classes, *mutatis mutandis:* the lecture is given, interspersed with questions, illustrations, and experiments, and the boys take rough notes which are re-cast into an intelligible and presentable form in note books. These are sent up about once a fortnight, looked over, corrected and returned; and they form at once the test of how far the matter has been understood, the test of the industry, care and attention of the boy, and an excellent subject for their English composition.

Examination papers are given to the sets every three or four weeks, and to these and to the note books marks are assigned which have weight in the promotion from form to form. The marks assigned to each subject are proportional to the number of school-hours spent on that subject.

There are school prizes given annually for proficiency in each of the branches of natural science above mentioned.

This leads us, lastly, to speak of the results :—

First, as to the value of the teaching itself; secondly, as to its effects on the other branches of study.

The experience gained at Rugby seems to point to these conclusions :—That botany, structural and classificatory, may be taught with great effect, may interest a large number of boys, and is the best subject to start with. That its exactness of terminology, the necessity of care in examining the flowers, and the impossibility of superficial knowledge are its first recommendations; and the successive gradations in the generalizations as to the unity of type of flowers, and the principles of a natural classification, are of great value to the cleverer boys. The teaching must be based on personal examination of flowers, assisted by diagrams, and everything like cram strongly discouraged.

Mechanics are found rarely to be done well by those who are not also the best mathematicians. But it is a subject which in its applications interests many boys, and would be much better done, and would be correspondingly more profitable, if the standard of geometry and arithemetic were higher than it is. The ignorance of arithmetic which is exhibited by most of the new boys of fourteen or fifteen would be very surprising, if it had not long since ceased to surprise the only persons who are acquainted with it; and it forms the main hinderance to teaching mechanics. Still, under the circumstances, the results are fairly satisfactory.

The geological teaching need not be discussed at length, as it is temporary, at least in the middle school. Its value is more literary than scientific. The boys can bring neither mineralogical, nor chemical, nor anatomical knowledge; nor have they observed enough of rocks to make geological teaching sound. The most that they can acquire, and this the majority do acquire, is the general outline of the history of the earth, and of the agencies by which that history has been effected, with a conviction that the subject is an extremely interesting one. It supplies them with an object rather than with a method.

Of the value of elementary teaching in chemistry there can be only one opinion. It is felt to be a new era in a boy's mental progress when he has realised the laws that regulate chemical combination and sees traces of order amid the seeming endless variety. But the number of boys who get a real hold of chemistry from lectures alone is small, as might be expected from the nature of the subject.

Of the value of experimental teaching in physics, especially pneumatics, heat, acoustics, optics, and electricity, there can be no doubt. Nothing but impossibilities would prevent the immediate introduction of each of these subjects in turn, into the Rugby curriculum.

Lastly, what are the general results of the introduction of scientific teaching in the opinion of the body of masters? In brief, it is this, that the school as a whole is the better for it, and that the scholarship is not worse. The number of boys whose industry and attention is not caught by any school study is decidedly less; there is more respect for work and for abilities in the different fields now open to a boy; and though pursued often with great vigour, and sometimes with great success, by boys distinguished in classics, it is not found to interfere with their proficiency in classics, nor are there any symptoms of over-work in the school. This is the testimony of the classical masters, by no means specially favourable to science, who are in a position which enables them to judge. To many who have left Rugby with but little knowledge and little love of knowledge, to show as the results of their two or three years in our middle school, the introduction of science into our course has been the greatest possible gain: and others who have left from the upper part of the school, without hope of distinguishing themselves in classics or mathematics, have adopted science as their study at the Universities. It is believed that no master in Rugby School would wish to give up natural science and recur to the old curriculum.

APPENDIX C.

On the Teaching of Science at Harrow School.

From this time forward, natural science will be made a regular subject for systematic teaching at Harrow, and a natural science master has been appointed.

But for many years before the Royal Commission of Inquiry into the Public Schools had been appointed, a voluntary system for the encouragement of science had been in existence at Harrow. There had been every term a voluntary examination on some scientific subject, which together with the text-books recommended, was announced at the end of the previous term. Boys from all parts of the school offered themselves as candidates for these voluntary examinations, and every boy who acquitted himself to the satisfaction of the examiners (who were always two of the masters) was rewarded with reference to what could be expected from his age and previous attainments. The text-books were selected with great care, and every boy really interested in his subject could and did seek the private assistance of his tutor or of some other master. The deficiencies of the plan, if regarded as a substitute for the more formal teaching of science, were too obvious to need pointing out; yet its results were so far satisfactory that many old Harrovians spoke of it with gratitude, among whom are some who have since devoted themselves to science with distinguished success.

One of the main defects of this plan (its want of all system) was remedied a year ago, when two of the masters drew up a scheme, which was most readily adopted, by which any boy staying at Harrow for three years might at least have the opportunity during that time of being introduced to the elementary conceptions of astronomy, zoology, botany (structural and classificatory), chemistry, and physics. These subjects are entrusted to the responsibility of eight of the masters, who draw up with great care a syllabus on the subject for each term, recommend the best text-books, and give weekly instruction (which is perfectly gratuitous) to all the boys who desire to avail themselves of it; indeed, a boy may receive, in proportion to the interest which he manifests in the subject, almost any amount of assistance which he may care to seek. Proficiency in these examinations is rewarded as before; and to encourage steady perseverance, the boys who do best in the examination during a course of three terms receive more valuable special rewards.

As offering to boys a voluntary and informal method of obtaining much scientific information, this plan (which was originated at Harrow, and has not, so far as we are aware, been ever adopted at any other school) offers many advantages. It is sufficiently elastic to admit of many modifications; it is sufficiently comprehensive to attract a great diversity of tastes and inclinations; it cannot be found oppressive, because it rests with each boy to decide whether he has the requisite leisure or not; it can be adopted with ease at any school where even a small body of the masters are interested in one or other special branch of science; and it may tend to excite in some minds a more spontaneous enthusiasm than could be created by a compulsory plan alone.

We would not, however, for a moment recommend the adoption of any such plan as a substitute for more regular scientific training. Its chief value is purely supplemental, and henceforth it will be regarded at Harrow as entirely subordinate to the formal classes for the teaching of science which will be immediately established. In addition to this, more than a year ago some of the boys formed themselves into a voluntary association for the pursuit of science. This Scientific Society, which numbers upwards of thirty members, meets every ten days at the house and under the presidency of one or other of the masters. Objects of scientific interest are exhibited by the members, and papers are read generally on some subjects connected with natural history. Under the auspices of this Society the nucleus of a future museum has already been formed, and among other advantages the Society has had the honour of numbering among its visitors more than one eminent representative of literature and science. We cannot too highly recommend the encouragement of such associations for intellectual self-culture among the boys of our public schools.—*From a Newspaper Report.*

MODERN SCIENTIFIC INVESTIGATION: ITS METHODS AND TENDENCIES.*

GENTLEMEN OF THE AMERICAN ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE: Every day of our lives we hear that this is an age of progress; and that it is so we find evidence at every turn. The rapidity with which effects follow causes in human events, the celerity with which the plan is carried into execution, gives to a year in the experience of one of the present generation the practical value of a lifetime in ages past. Much labour has been expended on the exposition of the causes of the mental activity of the present age, and of the grand achievements which have attended it; and yet, the key to the whole enigma is to be found in the universal adoption of the comparatively new system of inductive reasoning. It would be foreign to my purpose to attempt to illustrate or defend this proposition, and I must therefore trust to its acceptance without argument, while we pass to consider that branch of the subject which more immediately demands our attention.

Although the progress of the age to which I have referred has been a matter of wonder and delight to all students of humanity and civilization, many of our best men have been somewhat alarmed and dizzied by it; and while accepting the achievements of modern industry and thought as full of present good and future promise, they are not a little concerned lest our railroad speed of progress should lead to its legitimate consequences, a final crash—not of things material, but of those of infinitely more value—of opinions and of faith. As often as it is boasted that this is pre-eminently an age of progress, that boast is met by the inevitable "but" (which qualifies our praise of all things earthly) "it is equally an age of scepticism." For the truth of this assertion the proof is nearly as palpable as of the other; and in view of the ruthlessness with which the man of the present removes ancient landmarks and profanes shrines hallowed by the faith of centuries, it is not surprising that many of the good and wise among us should deplore a liberty of thought leading, in their view, inevitably to license; and mourn over this wide-spread scepticism as an

* An address delivered before the American Association, at Burlington, August, 1865, by Prof. J. S. Newberry, President of the Association; from a copy communicated by the Author.

evil and inscrutable disease that has fallen upon the minds and hearts of men.

Now for ev'ery consequence there must be an adequate cause; and while confessing the fact of this modern lack of faith, I have thought that a few moments given to an analysis of it, and an attempt to trace it to its source, might not be wholly misspent—might possibly, indeed, result in giving a grain of encouragement to those who look with distrust and dread upon the investigations and discussions which now occupy so large a portion of the time and thought of our men of science.

If the wheels of time could, for our benefit, be rolled back, and we could see in all its details the civilization of Europe three or four hundred years ago, we should find that our so much respected ancestors, who fill so large a space on the page of history, were little better than barbarians. Among the English, the French, the Germans, Spanish and Italians, we should find a phase of civilization which, excepting that it included the elements—as yet but imperfectly developed—of a true religious faith, is scarcely to be preferred to that of the Chinese. Aside from the vast difference perceptible between the civilization of that epoch and ours, as exhibited in the political condition of the people, in their social economy and morals, the general intellectual darkness of the period referred to could not fail to impress us both profoundly and painfully. Out of that darkness and chaos have come, as if by magic, all our modern democracy with its individual liberty and dignity, all our civil and religious freedom, all our philanthropy and benevolence, all our diffused comfort and luxury, most of our good manners and good morals, and all the splendid achievements of our modern scientific investigation.

It is unnecessary for me here to describe in detail the origin and growth of modern science. That has been so well done by Dr. Whewell that all men of education are familiar with the steps by which the grand, beautiful, and symmetrical fabric formed by the grouping of the natural sciences has acquired its present lofty proportions.

Previous to the period when the Baconian philosophy was accepted as a guide in scientific investigation, but one department of science had attained a development which has any considerable claim to our respect. Mathematics, both pure and applied, had been assiduously cultivated from the remotest antiquity, and with a degree of success which has left to modern investigators little more *than the elaboration of the thoughts of their* predecessors. In Metaphysics—which had claimed even a larger share of the attention of the scholars of antiquity—little progress had been made. Perhaps I am justified in saying little progress was possible, inasmuch as in the light of all the great material discoveries of modern times the metaphysicians of the present day are debating, with as little harmony of opinion, the same questions that divided the rival schools of the Greeks. Each successive generation has had its two parties of idealists and realists, who have discussed the intangible problems which absorbed the great minds of Plato and Aristotle with a degree of enthusiasm and energy—and it may be of acrimony—which seems hardly compensated by any expansion of the human intellect or amelioration of the condition of mankind.

Of the Physical Sciences we may say that, except Astronomy, no one had an existence prior to the time of Bacon. There were men of vast learning, and much that was called science in the mass of reported observation that had been accumulating from century to century, until it had become "*rudis indigestaque moles*," in which—though it constituted the pride of universities, the intellectual capital with which the savant thought himself rich, and that on which the professional man depended for success—there was far more error than truth, and its study was sure to mislead and likely to injure. In these circumstances the task before the scientific reformer was one far more difficult than that of clearing the Augean stables; no less, in fact, than to seat himself before this great heap of rubbish, this mass of truth and error,—of the sublimest philosophy with the wildest fiction,—to patiently winnow out the grains of truth, and from infiniteismal facts build up a fabric that should have a sure foundation below, and beauty and symmetry above. What more natural, then, than that the process adopted in winnowing this chaff-heap should be that which had given success to the only true science of the period?—that the mathematical touchstone should be the test by which every grain was tried? And such precisely was the course pursued; perhaps we may even say the only one practicable. Provided with this test, the reformer was compelled to rejudge upon its merits every proposition submitted to him, and accepted only as true such as could be demonstrated. The materials which composed the science to be reformed naturally fell into several categories. First,—That which had been demonstrated to be true. Second,

—That which was demonstrable. Third,—That which was probable. Fourth,—That which was possible; and fifth,—That which was impossible. Of these he systematically rejected all but the first and second classes. And this, in few words, has been the method adopted, not only in the purification of old science, but in the creation of new.

It will be seen at a glance, that in this process all that was contrary to the order of nature (supernatural or spiritual) was necessarily excluded; and it was taken for granted that the mathematical or logical faculty of the human mind was capable of solving all the problems of the material universe. Sir William Hamilton and others have demonstrated the inadequacy of mathematical processes as a guide to human reason, and a moment's thought will show us that our boasted intellect is incapable of grasping even all the material truths which are plainly presented to it. To illustrate: as we scan the heavens of a clear evening, we recognize the fact that we stand as it were on a point in space where our field of vision is limitless; the heavenly bodies stretching away into the realms of obscurity, and becoming invisible only through the imperfection of our organs of vision. Bringing to our aid the most powerful telescopes, we are apparently as far as ever from reaching the limits of the universe; and when we endeavour to conceive of such a limit, the reasoning faculty finds itself incapable of grasping either of the two alternatives offered to it, one or the other of which must be true. The universe must be either limited or limitless. But no man can conceive of a universe without a limit; and if it be regarded as terminated by definite boundaries, the imagination strives in vain to fill the void which reaches beyond. In fact, we stand here face to face with infinity, and recognize the fact that the infinite exists without the power to comprehend it.

The same is true of time. We cannot conceive of its beginning or its end. All things which come within the scope of our senses are limited in duration and circumscribed in space, and though we prate flippantly of the infinite, the pretence that we can grasp it is simply talk.

Conducted on such a plan, it was inevitable that scientific investigations should be narrow and materialistic in their tendency. No matter how strong the probability in favor of the truth of a certain proposition,—though the whole fabric of society were based upon its acceptance, and it formed the foundation of civil and moral laws, even though it controlled the actions of the philosopher himself,—if not proved consistent with nature's physical and material laws, it must be rejected as unworthy to enter into the construction of the edifice he was erecting. In his great task of undoing the work of blind, unreasoning faith, and wild, illogical speculation, all the fruit of such faith or speculation must be looked upon as matter valueless to his hand. We may even go further and say that were it true that the Supreme Intelligence had created the material universe, and by special providence modified or thwarted the general laws through which that universe was governed, such divine supervision and such miraculous interposition must necessarily have been ignored.

Let it not be inferred, however, that each and all of the great men who have been engaged in this work of scientific reformation were necessarily driven to be impious iconoclasts, or that in their efforts to emancipate themselves from time-honored errors, they necessarily prostituted the liberty they gained to selfish or sensual purposes. On the contrary, the most important advances which the human intellect has made within these latter centuries have been due to the efforts of men of the purest and most conscientious character; men whose lives were devoted with the utmost singleness of purpose to determine "what is truth;" men who, knowing that all truth must be consistent with all other truth, were willing to go whithersoever it should lead. If it shall prove that they have been occupied with "mint, anise, and cumin," omitting the "weightier matters of the law," it is also true that in no other way could the material laws of the universe be thoroughly investigated than by making them the subjects of an absorbed and undivided attention. It would be as just to impugn the motives and decry the merits of the maker of our almanacs because his mathematical calculations were not interlarded with moral maxims, as to reproach the student of natural phenomena because he did his work so well, and left to others the co-ordination of the results of his efforts with the accepted dogmas of religious faith. And it is not true, in any sense, that these devotees of science have lived in vain; for to them we mainly owe the fact that man is not only wiser now than formerly, but that he is better and happier.

In justice to the man of science we must claim for him the position of co-laborer with, and indispensable ally to, the philanthropists and moralists: for from no source have they drawn richer lessons, stronger arguments, or more eloquent illustrations than from his discoveries.

And yet, while conceding conscientiousness and purity of motive to the vast majority of our men of science, and acknowledging the contributions they have made and are making to human happiness, compelled by my sense of justice to defend their spirit, approve their methods, admire their devotion, and assert their usefulness, I cannot deny that the tendency of modern investigation is decidedly materialistic. All natural phenomena being ascribed to material and tangible causes, the search for and analysis of these causes have begotten a restless activity and an indomitable energy which will leave no stone unturned for the attainment of their object. But while this is apparent, and, indeed, inevitable, as has been seen from the sketch of the growth of modern science, I am far from sharing the alarm which it excites in the minds of many good men. Nor would I encourage or excuse that spirit of conservatism—to call it by no harsher term—which, for the safety of a popular creed, would by any and all means repress, and, if possible, arrest investigations that, it is feared, may become revolutionary and dangerous.

Such opposition, in the first place, must be fruitless. All history has proved that persecution by physical coercion or obloquy is powerless to arrest the progress of ideas, or quench the enthusiasm of the devotees of a cause approved by their moral sense. The problems before our men of science must be solved in the manner proposed, if human wisdom will suffice for the task. In every department of science are men actuated simply by a thirst for truth, whom neither heat nor cold, privation nor opposition, will hold back from their self-appointed tasks. We may, therefore, accept it as a finality, that this problem will be carried to its logical conclusion.

In the second place, if possible, the arrest of scientific investigation would be not only undesirable, but an infinite calamity to our race. As has been so often said, truth is consistent with itself. If, therefore, our faith in this or that is based on truth, we have no cause for fear that this truth will be proved untrue by other truths. And more than this: it seems to me that, in the reach and thoroughness of this material investigation, we may hope for such demonstration of the reality of things immaterial as shall produce a deeper and more universal faith than has ever yet prevailed.

Through this very spirit of scepticism which pervades the modern sciences we are compelled to exhaust all material means before we can have recourse to the supernatural. When, however, that has been done, and men have tried patiently and laboriously, but in vain, to refer all natural phenomena to material causes, then, having proved a negative, they will be compelled to accept the existence of truth not reached by their touchstone, and faith be recognized as the highest and best knowledge.

That such will be the result is the confident expectation of many of the wisest of the scientific men whose influence is looked upon with such alarm by those who, in their anxiety for their faith, demonstrate its weakness.

Already, as it seems to me, scientists have reached the wall of adamant—the inscrutable—that surrounds them on every side, and, ere long, we may expect to see them return to that heap of chaff from which the germs of modern science were winnowed, with the conviction that there were there left buried other germs of other and higher truths than those they gleaned; truths without which human knowledge must be a dwarfed and deformed thing.

A few illustrations from the many that might be cited will suffice to show the materialistic tendency of modern science. In "Pure Philosophy,"—as the students of Psychology are fond of styling their science,—the names alone of Compte, Buckle, Herbert Spencer, Mill, and Draper, will suggest the more prominent characters of the school they may be said to represent. The most conspicuous feature in the "Positive Philosophy" of Compte is the effort it exhibits to co-ordinate the laws of mind with those of matter. Spencer is a thorough-going mental Darwinist, who considers the highest attributes of the human mind, the loftiest aspirations of the soul, as only developed instincts, as these were but developed sensations. Mill, more guarded, more fully inspired with the spirit of the age,—which believes nothing, and is a foe to speculation,—leaves the history of our faculties to be written, if at all, by others; takes them as they are, but reasons of conscience and free-will with an independence of popular belief that savors more of the material than the spiritual school. Buckle wore himself out in a vain chase after an *ignis fatuus*, an inherent, inflexible law of human progress, and hence of human history. Draper is a developmentist, but not a Darwinian. With him civilization is a definite stage in the growth of mind; a degree of development to which it is impelled by a *vis a tergo*, not unlike, in kind, to that which evolves from the germ, the bud, the leaf, the flower, and the fruit in plant-life,—a development which, when unchecked and free, will be regular and inevitable, but which is so modified by the accidents of race, climate, soil, geographical position, etc., as to render it difficult to say whether the rule or the exception has, in his judgment, greatest potency. If he were a consistent Darwinist, the accidents of development would be its law.

Among the students of "Social Science,"—a new and important member of the sisterhood of sciences,—as in most of the other departments of modern investigation, two groups of devotees are found; one patiently and conscientiously studying the problems of social organization, inspired with the true spirit of the Baconian Philosophy, ready to follow whithersoever the facts shall lead, and having for their object that noblest of all objects, the increase of human happiness. The other class of investigators, in whom the bump of destructiveness is largely developed, would be delighted to tear down the whole fabric of society, and abrogate all laws, both human and divine. Looking upon man as literally the creature of circumstances, as an inert atom driven about by material forces, conscience and responsibility are by them repudiated, and laws and penalties regarded simply as relics of barbaric despotism. The dreary soul-killing creed of these fatalists is fortunately so repugnant to the reason and feelings of the majority of men, that there is little danger that their efforts will reach their legitimate conclusion in throwing society into a state of anarchy and chaos.

In Theology or Biblical Science the tendency of modern investigation is so distinctly felt, that I need only refer to it. The spirit of independent criticism, so noticeable elsewhere, is still more conspicuous here; assuming sometimes the form of derisive scepticism, but oftener of cold, passionless judgment on the reported facts of sacred history, or the psychological phenomena of religious faith, studied simply as scientific problems.

The names of Strauss, Renan, and Colenso, will suggest the results to which men, possibly honest, are led by this so-styled "enlightened and emancipated spirit of enquiry;" while "Ecce Homo" and cognate productions may be considered as the fruit of this spirit, tempered by a very liberal but apparently sincere faith.

Aside from these more marked examples of the decided "set" in the tide of modern religious opinions, we everywhere see evidences that no part of the religious world is unmoved by it. In every sect and section an impulse is felt to substitute for abstract faith, the "faith without works"—*rather a characteristic* of the religion of our fathers, and not unknown at present—that other faith which is evidenced by works. In other words; in our day more and more value is being attached to this life, as a sphere for religious effort and experience. With what propriety, I leave to the individual judgment of my auditors; the faith of every sect and man is coming to be respected and valued precisely in the ratio of the purity, unselfishness, and active sympathy in the life produced by it.

While, therefore, we have less now than formerly of the self-centred and fruitless piety of the old deacon whom I chanced to know, who excused his avarice by proclaiming that 'business was one thing and religion another, and he never allowed them to interfere;' in place of that we have many an Abou Ben Adhem, and all the splendid exhibitions of modern philanthropy.

Though the golden mean displayed in the life and words of Christ is far better than either extreme, I cannot but think the present religious condition of the world is better than any which has preceded it.

In Ethnology—the pre-historic history of the human race—the researches of the large number of investigators who are devoted to its study have made interesting and important additions to our knowledge; but it cannot be denied that the result of such investigation has been to create general distrust of our previously accepted chronology, and give an antiquity to man such as the scholars of a previous generation would have looked upon as not only unwarranted but impious. It should be said, however, that our preconceived opinions of the antiquity of the human race—like those of the age of the earth itself—were based upon no solid foundation in nature, history, or revelation; and that our system of chronology was a matter of convention, about which there has been a wide latitude of opinion among the scholars of all ages.

In regard to the origin of man—whether by special creation or development—we may confidently assert, that modern investigation has given us no new light. Among those who have accepted the theory of a special creation, and have differed only in regard to the number of species and their places of origin or centres of creation, there has been such a diversity of opinion that all confidence in the reality and value of the bases of their reasoning has been lost. Among the advocates of a multiplicity of species and diversity of origin we have from Blumenbach to Agassiz almost every number between fifteen and three as that of distinct species of the human race, scarcely any two writers advocating the same number. We may, therefore, very fairly infer that the facts upon which their conclusions are founded are not of a very clear and unmistakeable character.

The subject of the origin of the human race brings us into the domain of zoölogy, and opens the wide question of the origin of species, which, of late years, has been shaking the moral and intellectual world as by an earthquake. While the various writers upon the origin of the human race were gathering with so much industry, and reporting with so much eloquence, the proofs of a diversity of origin, the Darwinian hypothesis comes in and refers, not only all the human family, but all classes of animals and plants, to an initial point in a nucleated cell.

It would be impossible for any one to discuss, in a fair and intelligent manner, the great question of the origin of species, in anything less than a bulky volume. The merest mention is, therefore, all we can give to it at the present time. Although the appearance of Darwin's book on the Origin of Species communicated a distinct shock to the prevalent creeds, both religious and scientific, the hypothesis which it suggests, though now for the first time distinctly formularized, was by no means new; as it enters largely into the less clearly stated development theories of Oken, Lamarck, De Maillet, and the author of the Vestiges of Creation. There was this difference, however, that in the developmental theories of the older writers the element of evolution had a place; the process of development had its main spring in an inherent growth, or tendency, such as produces the evolution of the successive parts in plant-life, while, according to Darwin, the beautiful symmetry and adaptation which we see in nature is simply the form assumed by plastic matter in the mold of external circumstances.

Although this Darwinian hypothesis is looked upon by many as striking at the root of all vital faith, and is the *béte noire* of all those who deplore and condemn the materialistic tendency of modern science, still the purity of life of the author of the Origin of Species, his enthusiastic devotion to the study of truth, the industry and acumen which have marked his researches, the candor and caution with which his suggestions have been made, all combine to render the obloquy and scorn with which they have been received in many quarters, peculiarly unjust and in bad taste. It should also be said of Mr. Darwin that his views on the origin of species are not inconsistent with his own acceptance of the doctrine of Revelation; and that many of our best men of science look upon his theory as not incompatible with the religious faith which is the guide of their lives, and their hope for the future. To these men it seems presumption that any mere man should restrict the Deity in His manner of vitalizing and beautifying the earth. To them it is a proof of higher wisdom and greater power in the Creator that He should endow the vital principle with such potency that, pervaded by it, all the economy of nature, in both the animal and vegetable worlds, should be so nicely self-adjusting that. like a perfect machine from the hands of a master-maker, it requires no constant tinkering to preserve the constancy and regularity of its movements.

This much I have said in view of the possible acceptance of the Darwinian theory by the scientific world. I should have stated *in limine*, however, that the Darwinian hypothesis is not accepted and can never be fully accepted by the student of science who is inspired with the spirit of the age. From the nature of things it can be proved only to a certain point, and while we accept that which is proven,—and for it sincerely thank Mr. Darwin,—that which is hypothesis, or based only upon probabilities, we reject, as belonging in the category of mere theories, to disprove or purify which the modern scientific reform was inaugurated. Much, too, may be said against the sufficiency of 'natural selection in the struggle of life,' from observations made upon the phenomena of the economy of nature. Necessarily, the action of the Darwinian principle must be limited to the individual, be literally and purely selfish; and if it can be proved that a broader influence pervades the created world, that something akin to benevolence enters into the organization of the individual, something which benefits others and not himself, one single fact establishing this truth would hurl the entire Darwinian fabric to the ground; or rather restrict it to its proper bearing upon the limits of variation, and the mooted question of 'what is a species?'

One of the most potent influences in the perpetuation of species is fecundity in the individual, whereas we see in social insects the economy of the community is best served by a total loss of this power in the great majority of the individuals which compose it.

This objection will perhaps be met by the Darwinians with the assertion that the community, in fact, constitutes an individual; but I must confess that I find it difficult to comprehend how the sterility of the workers in ants and bees was ever introduced through the medium of modified descent, the Darwinian method, or how it is kept up from generation to generation among those individuals which have no posterity to inherit their peculiarities of structure.

The Honey Ants of Mexico offer additional difficulties. Among them a portion of the community secrete honey in the abdominal cavity until they resemble small grapes, and these individuals, during the winter, are despatched in succession to furnish food for the other members of the colony. How, by modified descent, is this honey-making faculty transmitted, when those who possess it are systematically destroyed?

A still harder nut for the Darwinians to crack is furnished in a fact stated by Dr. Stimpson, that among the crustacea, which do not live in communities, a very large proportion of the individuals of a numerically powerful species pass their lives as neuters, or undeveloped females.

Another element in nature's economy, which at first sight suggests an objection to the Darwinian theory, is that of beauty, which affects others far more than the possessor. This is considered by the Darwinians simply as an attraction to the opposite sex, but as a fact we find that in the larval condition of some insects—a condition in which no propagation is effected—varieties of form and combinations of color exist which appeal to our sense of beauty scarcely less forcibly than in the perfect insects.

Again, the origin of life is left completely untouched by the Darwinian hypothesis, and so long as the vital principle resists, as it has done, all efforts of theorists and experimenters to bring it within the category of material forces, so long we must regard the world of life as including elements not amenable to the laws which control simple inert matter.

Upon this question of the origin of life so much is being done and said that you will expect a word of reference to it at my hands, yet little more can be reported as the result of modern research than that the origin of life is as great a mystery as ever. You will all remember how, a few years since, we were startled by the announcement of the discovery of the generation of the *Acarus Crossii;* and, while our original distrust of the accuracy of the observations of Mr. Crosse was strengthened by the failure of subsequent experimenters to reproduce his results, our belief is further confirmed by the unanimity of all the more modern and intelligent devotees of spontaneous generation in the assertion *that life can only* originate in its simplest form, that of a unicellular organism. There is no Darwinist who will concede the possibility of an animal as highly organized as an Acarus, with body, head, limbs, digestion, and senses, all more or less complete, being the product of spontaneous generation and not the result of slow and gradual development.

Still farther; it is known that the animal kingdom rests upon the vegetable as a base. Animals being incapable of assimilating inorganic matter could not exist without plants. Plants must therefore have preceded animals, and the fruit of spontaneous generation must be a prototype and not a protozoan.

Strange as it may seem, there are, however, men, respectable by their numbers and attainments, who are believers in spontaneous generation; but it is with this proviso—which leaves the mystery as great as ever—that only from organic matter can organisms be produced. So that to the original and primary appearance of life upon the earth modern science has given us not the slightest clue.

As I have said, the materialists have so far utterly failed to co-ordinate the vital force with those which we designate as material. The beautiful and important discoveries which have followed researches into the correlation and conservation of forces, by pointing to a unity of all the forces in the material world, have naturally prompted efforts to centralize, with electricity, magnetism, and chemical affinity, that which we know as vital force. But a moment's reflection will show us how far removed is this vital force from all others with which it has been compared.

The nicest manipulations of chemical science will probably fail to detect a difference in composition between the microscopic germs of two cryptogamous plants. Each consists of the same elements, carbon, nitrogen, hydrogen, and oxygen, in nearly or quite the same proportions. Both may be planted in a soil which laborious mixture has rendered homogenous, and subsequently supplied with the same pabulum, and yet, in virtue of some inscrutable, inherent principle, one develops a humble moss, and the other rises into the beauty, symmetry, and even grandeur of a tree fern. The same may be said of the spermatozoa of the mouse and the elephant. Indeed all the phenomena which attend the reproduction of species are totally at variance and incompatible with those which mark the action of material laws. Why, in physical circumstances differing *toto cælo*, does the germ produce a plant or animal so closely copying the parent? and whence this tenacity of purpose in the germ which reproduces, through a long line of posterity, the trivial characteristics of a remote ancestor? Even within our limited observation we have been struck by the reappearance in the grandchild of the voice, the gesture, the stature, the features, or some other marked peculiarity of his grandsire. Whence comes the force of the axiom that 'blood will tell'?—and how incomprehensible that, by the action of only material laws, mental force, or, it may be, moral infirmity, is transmitted from generation to generation, in spite of the system of infinitesimal dilution through which it passes!

And now, even with this hurried and sadly imperfect exposition of the tendency of modern science, the time at our command has been consumed. Before leaving the subject, however, I crave your indulgence for a word to those who, wholly absorbed in the study of the laws which regulate the material universe, are so deeply impressed with their universality and potency, that they forget that law is but another name for an order of sequence, and has in itself no force. These are they who, in their pride in the achievements of the human intellect, fail to realize that the universe furnishes conclusive proof that all our philosophy, all our logic, all our observation are utterly inadequate to solve the problems that are presented to us; inadequate not simply from the limited nature of our powers of observation, but because the human mind, though forced to confess the existence of the infinite, is utterly unable to grasp it; and that while the logic of reason and the logic of numbers suffice for a qualified understanding of the manner in which material forces work, of the origin and nature of these forces we are and must ever remain ignorant, unless gifted with higher powers than we now possess. As has been stated, seen from the stand-point of our modern materialists, and judged by the criteria which they have adopted, spiritual existence and supernatural phenomena, even if as all-pervading as the most devout religionist believes, must, from *a priori* considerations, be utterly ignored. Of those who are thus led by their regard for the dignity of material laws to reject the idea of a creative and overruling Deity, I would ask, Is not man himself a disturbing element in your universe? Whatever may be said in regard to man's free-agency, and however confidently it may be asserted that his will is but the resultant of the various motives that operate as distinct forces upon it, consciousness lies at the base of all reasoning; and the conduct of every man proves that he accepts this axiom. As he issues from his door he is conscious, beyond all argument, that it is in his power to turn to the right or to the left; and while he holds himself responsible for his volition, he cannot blame us if we ascribe to him free-agency. Man is therefore an independent power in the universe. He wills and creates. The locomotive is as truly his creation as himself, fashioned from the dust of the earth and vitalized by the breath of the Almighty, is the work of His hands. If, therefore, all the realm of nature is controlled through material laws, by forces that, like attraction, electricity, chemical affinity, etc., act in an invariable and inflexible way, in this universe man is a stupendous anomaly; and unless he can be degraded from his position of pre-eminence in this material world, the boldest and most irreverant of modern philosophers will strive in vain to dethrone the great Creator from the rule of the universe, or from His place in the hearts and minds of men.

AMERICAN ASSOCIATION

FOR THE ADVANCEMENT OF SCIENCE.

The sixteenth annual meeting of the American Association for the Advancement of Science, was held in Burlington, Vermont; under the presidency of Professor J. S. Newberry, of Columbia College, New York; commencing on Wednesday, Aug. 21, and closing on Monday, Aug. 26, 1867.

The attendance was larger than at the Buffalo meeting in 1866; but still below that at the meetings held before the suspension of the Association's active work, rendered necessary by the late American war.

The papers presented were not very numerous; but nearly all were of great scientific value; bearing on controverted questions, applying the results of investigation to the determination of natural laws, or suggesting new fields and methods of research. A few comprised nothing beyond local details, which, if published, might have been of some service; but which should not have come before the Association. We give above the annual address of the President, and the following abstract of most of the papers read in the Natural History section, acknowledging our indebtedness to Prof. Newberry, and other members; and to the editors of the *American Naturalist*, for notes of papers, and proofs, kindly furnished us.

CONSIDERATIONS DRAWN FROM THE STUDY OF THE ORTHOPTERA OF NORTH AMERICA; by S. H. SCUDDER, of Boston. – This paper was a lengthened, comparative view of the North American and European orthopterous faunas. The groups characteristic of each continent were detailed, and the conclusion inferred, that, under similar climatic and other conditions, this family of insects is much richer in species and individuals in North America than in Europe.

TRACES OF ANCIENT GLACIERS IN THE WHITE MOUNTAINS OF NEW HAMPSHIRE; with a few remarks upon the geological structure of that part of the group.—The author recounted the observations made by him on the geological structure and grouping of the rocks in the region of the Androscoggin, Peabody, and other valleys in the White Mountains, and the traces they bear of glacial action. His observations tended to confirm the opinion that these valleys have been occupied by local glaciers, as well as by a general one.

ON THE ORIGIN OF THE LIGNILITES, OR EPSOMITES; by Prof. O. C. MARSH, Yale College, New Haven.—These names have been applied to the columnar markings, and more or less detached columns, occurring in the seams between strata, among limestone rocks of all ages. Prof. Marsh, after stating the conflicting opinions hitherto held and published by geologists, on the cause of the structure, exhibited a fine series of specimens, showing it to be due to pressure. He has found that a shell, or other foreign substance, often forms the nucleus of one of these columns.

THE FOSSIL INSECTS OF NORTH AMERICA; by S. H. SCUDDER.—This paper was a summary of all that is yet known on the subject. Eighty species have been determined and described; while a few fragments are so badly damaged that it is impossible to identify them. The Orthoptera have the greatest number of representatives in the North American rocks; and no species of coleoptera has yet been found. The oldest of our known fossil insects are from the Devonian strata of New Brunswick; while in Tertiary rocks their remains have been found in only one locality, near Green River, Colorado. No fossil spiders have been discovered in North America.

ON THE WINOOSKI MARBLE OF COLCHESTER, VT.; by Prof. C. H. HITCHCOCK.—This beautiful marble, which is found in Potsdam rocks, near Burlington, consists of a silicious dolomite, containing imbedded nodules of silica, enclosed in calcite. The prevailing color is red, mottled, and veined with white, brown, chocolate, yellowish, and whitish tints. So highly is it valued abroad, that considerable quantities are exported to Italy for the use of the sculptors of that country. The presence of the quartz, however, renders it somewhat difficult to work.

ON THE ZOOLOGICAL AFFINITIES OF THE TABULATE CORALS; by Prof. A. E. VERRILL.—The questions discussed in this paper were the position of the tabulate corals among Polyps, and the true value of the tabulate structure in classification. Coral-like forms are produced by Protozoa (Eozoon, Polytrema, Sponges, etc.), Mollusean corals (Bryozoa), Hydroid corals (Sertularia, etc.), Polyp corals (Gorgonia, Tubipora, Madrepora, etc.), and by vegetable corals (Nullipora, Corallina). Most of these have been carefully studied. Two important groups, however, are still involved in considerable doubt,—the Cyathophylloid corals (Rugosa, Edw.), and the Tabulate corals. The former are entirely extinct, and their structure may long remain somewhat uncertain The latter are represented in tropical seas by several genera and numerous species. Usually they have been considered true Polyps; but some zoologists urge their affinity with the Bryozoan mollusks, while Agassiz, after examining the genus Millepora, places the whole group among Hydroids. Prof. Verrill considered the point as only settled so far as Millepora and its allies were concerned, and requested Mr. F. H. Bradley, while collecting, at Panamá, for the Yale College Museum, to study the structure and habits of a species of Pocilopora found at the place. The descriptions and figures of the animal show it to be a true Polyp, scarcely differing from Porites, except in the position of the tentacles. The animals are exsert when expanded, and have twelve equal cylindrical tentacles surrounding the margin, in a single circle, six of them being held horizontally, and the alternate ones erect. Prof. Verrill, therefore, concludes that the tabulate structure is of secondary importance as a character, in fixing their affinities, and that the Tabulata must be dismembered,—Halisites, Millepora, and their allies, being classed as Hydroids; and Pocillopora and Favosites with other extinct tabulated genera, as true Polyps.

ON THE COAL MEASURES OF ILLINOIS; by Prof. A. H. WORTHEN, State Geologist.—In prosecuting the geological survey of Illinois, it seemed desirable to identify the coal seams of that State with those of Kentucky, which occupy the same basin. To effect this, a section was constructed along the valley of the Illinois River, which traverses the coal-field from S.W. to N.E. for about 100 miles. Six beds of workable coal, and four or five thin seams, were met with in the section. After correcting an error, which he thinks had been made in constructing the Kentucky section, by considering the outcrop of the same sandstone at Mahoning and Anvil Rock as different beds, Prof. W. found a very close resemblance between the Illinois and Kentucky strata. From his observations, he infers the existence of coal seams over wide geographical areas. The fact was also stated that many of the fossils of the carboniferous limestone, in this region, are identical with those described by Hayden and Meek, from the so-called sub-carboniferous rocks of Eastern Kansas.

ON RECENT GEOLOGICAL DISCOVERIES IN THE ACADIAN PROVINCES OF BRITISH AMERICA; by J. W. DAWSON, LL.D., F.R.S., Principal of McGill University. The object of the paper was to notice some recent discoveries, which, though of interest, might have escaped the notice of members of the Association.

In New Brunswick, the older rocks in the vicinity of the city of St. John have been reduced to order, and their probable ages ascertained, principally through the labors of Mr. Matthew, Mr. Hartt, and Professor Bailey. The first step toward the knowledge of their precise date was the discovery of a rich land flora in some of the upper beds, next below the Lower Carboniferous rocks which overlie them unconformably. These fossil plants he was enabled to recognize as of the Devonian Period, and the zealous researches, more especially of Mr. Hartt, have brought to light no less than forty to fifty species, or half of the whole number known in the Devonian of Eastern America, as well as six species of insects, four of which have been described by Mr. Scudder.*

* Canadian Naturalist. 1867.

These insects are the first ever found in rocks older than the Carboniferous.

These rocks, consisting chiefly of hard shales and sandstones, having been ascertained to be Devonian, there still remained an immense thickness of underlying rocks of uncertain age. In the upper member of these rocks, the same active observers already mentioned have observed a rich primordial fauna, embracing species of Conocephalites, Paradoxides, Microdiscus, and Agnostus, as well as an Orthis, and a new type of Cystidians. These fossils are regarded by Mr. Hartt and Mr. Billings as of the age of Barrande's "Etage C," and as marking a new and older period of the "Silurian Primordial" than any other as yet recognized in America, with the exception of the slates holding Paradoxides in Massachusetts, and the similar slates of the "Older Slate Formation" of Jukes, in Newfoundland. Descriptions of these fossils, by Mr. Hartt, will be published in the edition of "Acadian Geology" now in press. It is proposed to call this series, represented in New Brunswick by the St. John slates, the *Acadian Series*.

Below these primordial beds are highly metamorphosed rocks, at least 9,000 feet in thickness, which have afforded no fossils. A portion of these, consisting principally of conglomerate and trappean beds, is regarded by Messrs. Matthew and Bailey as of the age of the Huronian. The remainder, containing much gneiss and a bed of crystalline limestone, they regard as Laurentian. If this view is correct, and it certainly seems to be probable, these rocks, thus rising through the oldest members of the Lower Silurian, and forming a stepping-stone between the Laurentian of Newfoundland and that of New Jersey, show that the foundations of the north-east and south-west line of the east side of North America were already laid in the Laurentian period. Still, it is not here, but farther west, that we are to look for the dividing line between the great inland Silurian basin of America, and that of the Atlantic coast; the latter has been pointed out by Professor Hall and Sir. W. E. Logan, as remarkably distinguished by the predominance of mechanical sediments, and by a development of the lower rather than the upper members of the Lower Silurian.

To ascend from these rocks to the Carboniferous,—recent labors of Mr. Davidson, Mr. Hartt, and the author, had led to the division of the Lower Carboniferous into successive subordinate stages, and to the determination of most of the marine fossils, and also to the explanation of the curious and apparently anomalous fact that some forms allied to Permian species actually exist in the Lower Carboniferous, under the productive coal-measures. These researches had, also shown that no distinction between Sub-carboniferous and Carboniferous proper, can fairly be made in Nova Scotia, notwithstanding the grand development of the Carboniferous in thickness.

After noticing the large advances made in the fossil botany of Nova Scotia and New Brunswick, the paper referred to the discovery by Mr. Barnes of two new species of insects, and to the discovery by the author of a new pulmonate mollusk, described by Dr. P. P. Carpenter as *Conulus priscus*. There are thus in the coal formation of Nova Scotia a Pupa and a Conulus or Zonites, generically allied to living pulmonates, and representing already in that early period two of the principal types of these creatures.*

Specimens of these fossils were exhibited, and also specimens and a photograph of the Laurentian fossil *Eozoön Canadense* sent by Sir. W. E. Logan. Special attention was drawn to the specimen recently found by the Canadian Survey at Tudor, which shows this organism in a state of preservation comparable with that of ordinary Silurian fossils.

On some remarkable fossil fishes, from the "Black Shale" (Devonian) at Delaware, Ohio; by J. S. Newberry. —Dr. Newberry exhibited to the Section different portions of the head of a gigantic fish, to which he had given the name of *Dinichthys Herzeri*; and which, he said, from its size and structure, deserved the same distinction among fishes that *Dinotherium* and *Dinornis* enjoy among mammals and birds. Most of the bones obtained as yet belonged to the head, which was over three feet long, by one and a-half broad, and wonderfully strong and massive. All parts of the head had been procured, and many different individuals were represented in the collections made by Mr. Herzer. The cranium was composed of a number of plates firmly anchylosed together, and strengthened near the occiput by internal ribs or ridges, nearly as large as one's arm. The external surface was covered with a very fine vermicular ornamentation. The anatomical structure was more wonderful than the size, and was such as to separate this quite widely from any fishes known, living or

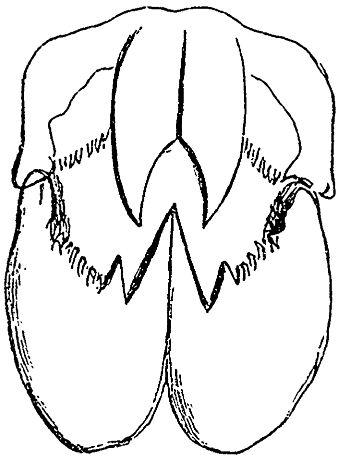
* Acadian Geology. Second Edition.

fossil. The most marked peculiarity was in the structure of the jaws and teeth, both as regards the form and texture. The form of the jaws will be best understood by the following figures.

Fig. 1.

Lower Jaw—one-eighth natural size.

Fig. 2.



Front view of Head—one-eighth natural size.

The head terminated anteriorly and above in two great incisors, representing the premaxillary, behind which on either side were the maxillaries—broad, flattened bones of very dense tissue—along the lower edge of which was set one row of small robust teeth, which were neither implanted in sockets nor cemented to the jaw, but were formed by the consolidation and prolongation of the jaw tissue. The mandibles are over two feet long by six inches deep, laterally flattened and very massive, being without any medullary cavity. The anterior extremity was turned up in a huge triangular tooth, composed of dense ivory-like tissue, which alternated with (passing between) the divergent incisors of the upper jaw. Back of this terminal tooth, on some specimens, was another triangular summit, behind which was a row of small teeth corresponding to those of the maxillaries. Such was the power of this tremendous dental apparatus, that the bodies of our largest living fishes would be instantly pierced and crushed by it, if exposed to its action. Behind the head were large and thick plates, one of which corresponded to the "*os medium dorsi*" of *Heterostius* (of Pander) being at least of equal size.

These interesting fossils were found in the calcareous concretions, which occur so abundantly near the base of the "Black Shale" (Hamilton) at Delaware, in Central Ohio, by Mr. Herzer, a clergyman, who, while performing his pastoral duties, and living on a very small salary, had been a most zealous and remarkably successful student of the local geology.

On some Fossil Reptiles and Fishes from the Carboniferous Strata of Ohio, Kentucky, and Illinois; by J. S. Newberry.—The specimens exhibited and described in this communication consisted of reptiles and fishes from the cannel stratum underlying the main coal seam at Linton, Ohio; of fishes from the coal measures of Illinois, collected by the State Geologist; and of a group of fishes collected by Dr. Patterson from a stratum of bituminous shale lying in the Waverly group, 125 feet above its base at Vanceburg, Kentucky. Of these, the first series included *Raniceps Lyellii* (Wyman) with several as yet undescribed reptiles, some of which apparently belong to Prof. Huxley's new genera, *Ophiderpeton* and *Urocordylus*. Associated with these were some twenty species of fossil fishes, most of which have been described by Dr. Newberry, but were now represented by new and more perfect specimens. Among these were eight species of *Eurylepis*, a genus created by Dr. Newberry to receive a group of small lepidoids, allied to *Palæoniscus*, but distinguished by the scales of the sides, which are much higher than long. The scales on several of these species are very highly ornamented. The specimens exhibited were preserved in cannel coal, and covered with a film of sulphide of iron, by which they were brilliantly gilded. With these were two species of *Coelacanthus*, some of the specimens of which showed that the fishes of this genus were furnished with a supplemental caudal fin, as in *Undina*. This, Dr. Newberry stated, was an interesting fact, confirmatory of Prof. Huxley's view of the relations of *Undina*, *Macropoma* and *Coelacanthus*. The numerous and very complete specimens of *Coelacanthus* exhibited, supply much that was wanting to a perfect knowledge of the anatomy of this genus. The bones of the head are similar in form to those of *Macropoma*, are highly ornamented with tubercles above and thread lines below; the jugular plates are double and long-elliptical as in *Undina* and *Macropoma*, but the teeth are conical and curved. The position and form of the fins is as in *Undina*, but the anterior dorsal is stronger. The fins are supported on palmated interspinous bones, similar in a general way to those of the other genera of the family. The paired fins are slightly lobed. The supplemental caudal has been referred to; the scales are ornamented with curved and converging raised lines. In many specimens the earbones (otolites) are distinctly visible. Besides the fishes found at Linton already enumerated, there were scales and teeth of *Rhizodus*, two species, at least one of which (*R. angustus*) has teeth of two forms,—one large, flattened, and double-edged; the others smaller, more numerous, slender, striated, and conical, with a circular section throughout; two species of *Diplodus*, consisting of bony base and enamelled crown,—the latter distinctly and beautifully serrated; so that there can scarcely be a question that they were teeth, and not, as claimed by Mr. Atthey, of Newcastle, England, dermal tubercles.

In the Linton fauna is one species of *Palaeoniscus* (*P. Scutigerus, N.*); one of *Pygopterus*; one of *Megalichthys*, represented by scales; and numerous spines of placoid fishes of the genera *Compsacanthus* and *Pleuracanthus*.

The fish remains from Illinois consisted of a splendid specimen of *Edestus vorax* (Leidy) from the coal at Bellville, opposite St. Louis, and of several individuals of a new species of *Platysomus* from the concretions of iron ore at Mazon Creek. The *Edestus* was said by Dr. Newberry to have been described as a jaw, but the specimen exhibited was much more complete than any before found, and there could scarcely be a doubt that it was the spine of a Selachian. *Platysomus*, he said, though common in the coal measures of England, had not been before found in America.

The fishes from the Waverly were from a new locality, and from a horizon that had furnished very few fossils of any kind, and no fishes except a *Palaeoniscus* (*P. Brainerdi*) found in northern Ohio. The specimens collected at Vanceburg, by Dr. Patterson, consisted of teeth of *Cladodus* and *Orodus*, with spines of *Ctenacanthus*, with the tail of one of these Selachians distinctly preserved. This Dr. Newberry said was a great rarity, as the soft, and even the cartilaginous parts of plagiostomous fishes had usually disappeared, the teeth, spines, and dermal tubercles—the only bony parts—alone remaining. The only similar case of which he had any knowledge was the discovery of the tail and fins of *Chondostreus*, in the Lias of Lyme Regis, England, and the preservation of *Thyalina* in the Solenhofen slate. The specimen shown was greatly older than these, being from the base of the Carboniferous, and was the only figure that nature has yet given us of the external form of these ancient sharks. This tail was very heterocercal, had the form of the caudal fins of some living sharks, and indicated a fish of seven or eight feet in length. In the specimen exhibited, the vertebral column had entirely disappeared, but the impressions of the spinous bones were distinctly visible, those of the lower lobe of the tail being ossified throughout. Dr. Newberry said that he hoped to gather data from this collection for uniting teeth and spines, which, though described under different names, were parts of one fish.

ON SOME NEW FOSSIL SPONGES FROM THE LOWER SILURIAN; by Prof. O. C. MARSH.—The author exhibited and described some specimens of the new genus Brachiospongia, from the Lower Silurian rocks of Kentucky. These sponges, of which a full account will shortly be published by Prof. Marsh, differ widely from all the species hitherto known, and are of great interest to science.

ON THE OCCURRENCE OF FOSSIL SPONGES IN THE SUCCESSIVE GROUPS OF THE PALÆOZOIC SERIES; by Prof. JAS. HALL.—This paper was an epitome of all that is known of the sponges of the Silurian, Devonian, Carboniferous, and Permian formations. Sponges with calcareous skeletons, and coral-like forms, were among the earliest inhabitants of the earth, being found in the Lower Silurian strata. In the Devonian age they were still more abundant; but from this period diminished in numbers, and became more like the horny sponges of the present day.

ON THE AMERICAN BEAVER; by LEWIS H. MORGAN, Rochester, N.Y.—The Beaver appears to be rapidly becoming extinct wherever civilization advances. It is still found, however, in certain localities, from Virginia to the parallel of 60 N. lat., though most abundant in the Hudson Bay Territory. Mr. Morgan had examined the dams constructed by them around the southern shore of Lake Superior. Some of these show an astonishing amount of instinct in the way of engineering. Trees many feet in diameter have been cut down by them; canals are often constructed from their ponds to the localities of the trees on the bark of which they feed—in one instance the canal measuring over 60 yards in length. Natural obstacles are overcome by means of bridges, tunnels, etc., built with great ingenuity.

On the metamorphosis and distortion of Pebbles in Conglomerate; by C. H. Hitchcock, State Geologist, Vermont.—Geologists have noticed that in certain highly disturbed localities, when a band of conglomerate can be traced from its normal position to that in which it is contorted and folded, the undisturbed stratum is simply a loosely cemented gravel with rounded pebbles, while in the plicated rocks the pebbles are distorted and flattened. Examples of this occur at Middleton, R. I., Plymouth, Vt., Nagelflue, in Switzerland, and the Permian conglomerate in England. The pebbles are not only distorted, but often changed in their chemical composition, impure limestones or schists being displaced by quartz, and probably the original sandstone and conglomerate changed into schists, gneiss, and granite. Prof. Hitchcock thinks that both the metamorphism and warping are due to the agency of infiltrated water under enormous pressure.

On the Lower Silurian Brown Haematite Beds of America; by B. S. Lyman.—Thirty exposures of the four beds of this ore have been studied in Western Virginia. Of these, three or four show the solid bed; the others only have weathered boulders of the ore, mixed with other detrital matter. In comparing these with other Brown Haematite deposits in the United States, the author infers that the lumps of ore, sometimes found mixed with the *debris* of other rocks, mark the proximity of beds of the Haematite, from which the blocks have been separated by denudation. From the frequent occurrence of carbonate of iron, he regards this as the original composition of the ore,—the carbonic acid having been driven off by heat, or other causes, and the protoxide changed to a sesquioxide.

Explanations of the Geological Map of Maine; by Prof. C. H. Hitchcock.—The author showed the large geological map, which embodied the results of work done by the State Survey during 1861-62, and called attention to several points of interest settled during that period.

On the geographical distribution of the Radiates on the West Coast of America; by Prof. A. E. Verrill.—Eleven distinct marine zoological provinces have been recognized along the coast, each characterized by the existence or prevalence of peculiar genera and species. These provinces were discussed by Prof. Verrill, in detail, the characteristic species, and the conditions under which they exist stated, the number of species of each class of Radiates known to exist in the several provinces, and number peculiar to the respective provinces given, and each Pacific shore region compared with parallel regions on the Atlantic coasts of America and Europe. Distribution is effected mainly by temperature, less by the nature of the bottom and shore. Depth of water exerts principally an indirect influence by diminishing the temperature as we descend. A few Holothurians are the only Radiates recorded as common to the Atlantic and Pacific. The Polyps and corals of the two seas differ widely. The mollusca, crustacea, fishes, and echinoderms are usually specifically distinct, but the genera and families of these groups are often identical. No direct evidence exists of a water communication across the Isthmus later than the cretaceous period. Prof. Verrill concludes that all the phenomena observed in the distribution of identical species may be accounted for by supposing a former depression of about 300 feet, which would cause a connection across the Isthmus by means of a shallow, brackish estuary, capable of sustaining the life of many mollusca, crustacea, and fishes, but not the genera of corals and other Radiates. In the case of distinct, but similar species, we must suppose different centres of creation, or a descent from common ancestors, the distribution having taken place at a very early period, when an extensive connection existed between the two oceans. The animals on the latter supposition have subsequently become distinct, by natural selection, or otherwise.

Considerations relating to the Climate of the Glacial Epoch in North America; by Prof. E. Hungerford.—The object of this paper was to discuss the growth, and climatic influence of such an accumulation of ice and snow as the glacial hypothesis supposes to have once existed. The result of an elevation of the northern part of the continent would be to lower the snow line by depressing the mean summer temperature. If the surface were raised by the accumulation of frozen snow, instead of by an upheaval of the land, the frigorific effect would be similar, but greatly intensified. Then every addition to this icy accumulation would depress still farther the temperature of the continent, and extend the area of perennial snow. The great northern ice plateau would thus increase in height and superficial extent until prevented by some reactionary cause. Meteorological considerations all show us that the interior of such a plateau would be intensely cold,—so cold as to prevent the simultaneous moving of the continental glaciers in one determined direction. Hence, the erosive effects which we witness are due to glacial motion along the southern and seaward edge of the glacier, where the snow is softened by the sun, or sea-breezes, and a slope supplied by the glacial front itself.

Depression of the Sea during the Glacial Period; by Colonel Charles Whittlesey.—The level of the ocean is maintained by the evaporated water being returned through rivers, etc. If part of this vapor, instead of returning, accumulate on the land as permanent snow and ice, the result will be a depression of the sea level, proportionate to the extent of the ice-fields. A decrease of one degree annually in the earth's temperature would lower the snow line 300 feet, extend the area of ice and snow, and diminish evaporation; while additions would be constantly made to the thickness of the ice beds. Now, as one-fifth of the earth must have been covered by ice fields during the glacial period, and the extent of the ocean at the time is known with considerable certainty, by knowing the thickness, and, consequently, the mass of the beds of ice, we can easily determine the decrease in the water of the sea. Ice etchings are observed on rocks in British America and New England, at heights varying from 1,500 to 5,300 feet above the present sea level. Admitting an average of 2,000 feet, and an expansion of one-tenth in freezing, we have a sufficient amount of congealed water to cover the above area to a depth of 1,800 feet. As nearly the entire remaining surface of the earth was covered with water, the surface would sink about one-fifth of the above, or 360 feet. The weight of such a mass of ice would probably be sufficient to cause a sinking of the land on which it rested, while that adjacent to it would be elevated; just as we see Greenland settling down, and Newfoundland rising, at the present day. These facts should be kept in mind in studying fresh water and marine terraces, and drift-beds. From the absence of these elevations on the Rocky Mountains above a height of 2,000 feet, that part of the continent seems to have been sinking, during the past glacial period, while the eastern sea-coast was rising,—the line of rest being near the middle of Lake Ontario.

On the Ripton Sea-beaches; by Prof. E. Hungerford.—This paper described a series of terraces, situated at a height of 2,196 feet above the sea, on the west flank of the Green Mountains, on the pass from Ripton to Hancock. They consist of a modified drift, overlying the true boulder drift of the region, and arranged in this present form by the action of waves and currents. As the configuration of the country would not allow the accumulation of a large body of fresh water at this point, these deposits are regarded as strongly confirming other evidence that this area has suffered a depression of at least 2,000 feet since the glacial epoch. The author regards the following as the successive geological events by which the drift phenomena have been produced:

1. The formation of a continental glacier, to whose partial movements, always limited to a comparatively narrow belt upon the southern or seaward margin, are due the erosive phenomena, and the transportation of the drift over limited areas.

2. A depression of the continent, bringing the ocean into contact with the long glacial border, which on its retreat sends off icebergs and ice-rafts into the ocean. To these are attributed the further transportation of detritus and boulders.

3. Emergence of the continent, the higher beaches marking the earlier, and the Champlain terraces the later stages of this process.

On certain effects produced upon Fossils by weathering; by Prof. O. C. Marsh.—Prof. Marsh has discovered that certain peculiarities observed in *Ceratites nodosus*, and other fossil shells, especially cephalopods, and which have long perplexed German geologists, are due to the action of the elements, the layers of the shell differing in composition, hardness, and markings. In some cases the markings characteristic of two distinct genera may be observed on the same specimen.

On the Geology of Vermont; by Prof. C. H. Hitchcock.—Prof. Hitchcock exhibited a large geological map of the State, showing the great progress made in determining the structure of its rocks, since the publication of his final Report upon the Geology of Vermont, in 1861. This is largely due to the extension southward of the recent discoveries of the Canadian survey.

On the Ichthyological Fauna of Lake Champlain;

by F. W. Putnam, Superintendant of the Essex Institute.—A list numbering 45 species of true lake fishes, obtained by the author from Lake Champlain, was given; of these, 41 were found by him in Lake Erie. As Lake Champlain was a salt-water bay at a period subsequent to the glacial epoch, while the lakes above Niagara Falls contained fresh-water, the weight of evidence goes to support the conclusion that the fishes of Lake Champlain have been chiefly derived from those higher lakes.

Among other business transacted before the close of the meeting, the following resolution was moved by Prof. O. C. Marsh, and adopted:—

"*Resolved*, That the chair appoint a commission of nine members to examine the Linnean rules of Zoological Nomenclature by the light of the suggestions and examples of recent writers, and to prepare a code of laws and recommendations in conformity with past modern usage, to be submitted to the Association at the next annual meeting; the committee to have authority to fill vacancies and increase the number to twelve, if deemed advisable."

The committee appointed consists of:—Prof. J. D. Dana, of Yale College; Prof. Jeffries Wyman, of Howard University; Prof. S. F. Baird, of the Smithsonian Institution; Prof. Joseph Leidy, of the Philadelphia Academy of Natural Sciences; Prof. J. F. Newberry, of Columbia College; Principal Dawson, of McGill University, Montreal; Dr. Wm. Stimpson, of the Chicago Academy of Science; S. H. Scudder, of the Boston Natural History Society; and F. W. Putnam, of the Essex Institute.

The next meeting will be held at Chicago, commencing on the first Wednesday of August, 1868. H.

ON NEW SPECIMENS OF EOZOON.

By Sir W. E. Logan, F.R.S., F.G.S.*

Since the subject of Laurentian fossils was placed before this Society in the papers of Dr. Dawson, Dr. Carpenter, Dr. T. Sterry Hunt, and myself, in 1865, additional specimens of *Eozoon* have been obtained during the explorations of the Geological Survey of Canada. These, as in the case of the specimens first discovered, have been submitted to the examination of Dr. Dawson; and it will be observed, from his remarks contained in the paper which is

* From the Quar. Jour. Geol. Soc. for August, 1867. Read before the Geological Society, May 8, 1867.

to follow, that one of them has afforded farther, and what appears to him conclusive, evidence of their organic character. The specimens and remarks have been submitted to Dr. Carpenter, who coincides with Dr. Dawson; and the object of what I have to say in connexion with these new specimens is merely to point out the localities in which they have been procured.

The most important of these specimens was met with last summer by Mr. G. H. Vennor, one of the assistants on the Canadian Geological Survey, in the township of Tudor and county of Hastings, Ontario, about forty-five miles inland from the north shore of Lake Ontario, west of Kingston. It occurred on the surface of a layer, three inches thick, of dark grey micaceous limestone or calc-schist, near the middle of a great zone of similar rock, which is interstratified with beds of yellowish-brown sandstone, grey close grained siliceous limestone, white coarsely granular limestone, and bands of dark bluish compact limestone and black pyritiferous slates, to the whole of which Mr. Vennor gives a thickness of 1,000 feet. Beneath this zone are grey and pink dolomites, bluish and greyish mica slates, with conglomerates, diorites, and beds of magnetite, a red orthoclase gneiss lying at the base. The whole series, according to Mr. Vennor's section, which is appended, has a thickness of more than 21,000 feet; but the possible occurrence of more numerous folds than have hitherto been detected, may hereafter render necessary a considerable reduction.

These measures appear to be arranged in the form of a trough, to the eastward of which, and probably beneath them, there are rocks resembling those of Grenville, from which the former differ considerably in lithological character; it is therefore supposed that the Hastings series may be somewhat higher in horizon than that of Grenville. From the village of Madoc, the zone of grey micaceous limestone, which has been particularly alluded to, runs to the eastward on one side of the trough, in a nearly vertical position into Elzivir, and on the other side to the northward, through the township of Madoc into that of Tudor, partially and unconformably overlaid in several places by horizontal beds of Lower Silurian limestone, but gradually spreading, from a diminution of the dip, from a breadth of half a mile to one of four miles. Where it thus spreads out in Tudor it becomes suddenly interrupted for a considerable part of its breadth by an isolated mass of anorthosite rock, rising about 150 feet above the general plain, and supposed to belong to the unconformable Upper Laurentian, thus showing that the specimens of *Eozoon* of this neighbourhood, like those previously discovered and described, belong to the Lower Laurentian series.

The Tudor limestone is comparatively unaltered; and, in the specimen obtained from it, the general form or skeleton of the fossil (consisting of white carbonate of lime) is imbedded in the limestone, without the presence of serpentine or other silicate, the colour of the skeleton contrasting strongly with that of the rock. It does not sink deep into the rock, the form having probably been loose and much abraded on what is now the under part, before being entombed. On what was the surface of the bed, the form presents a well-defined outline on one side; in this and in the arrangement of the septal layers it has a marked resemblance to the specimen first brought from the Calumet, eighty miles to the north-east, and figured in the 'Geology of Canada,' p. 49; while all the forms from the Calumet, like that from Tudor, are isolated, imbedded specimens, unconnected apparently with any continuous reef, such as exists at Grenville and the Petite Nation. It will be seen, from Dr. Dawson's paper, that the minute structure is present in the Tudor specimen, though somewhat obscure; but in respect to this, strong subsidiary evidence is derived from fragments of *Eozoon* detected by Dr. Dawson in a specimen collected by myself from the same zone of limestone near the village of Madoc, in which the canal-system, much more distinctly displayed, is filled with carbonate of lime, as quoted from Dr. Dawson by Dr. Carpenter in the Journal of this Society for August, 1866.

In Dr. Dawson's paper mention is made of specimens from Wentworth, and others from Long Lake. In both of these localities the rock yielding them belongs to the Grenville band, which is the uppermost of the three great bands of limestone hitherto described as interstratified in the Lower Laurentian series. That at Long Lake, situated about twenty-five miles north of Côte St. Pierre in the Petite Nation Seigniory, where the best of the previous specimens were obtained, is in the direct run of the limestone there; and like it the Long Lake rock is of a serpentinous character. The locality in Wentworth occurs on Lake Louisa, about sixteen miles north of east from that of the first Grenville specimens, from which Côte St. Pierre is about the same distance north of west, the lines measuring these distances running across several important undulations in the Grenville band in both directions. The Wentworth specimens are imbedded in a portion of the Grenville band which appears to have escaped any great alteration, and is free from serpentine, though a mixture of serpentine with white crystalline limestone occurs in the band within a mile of the spot. From this grey limestone, which has somewhat the aspect of a conglomerate, specimens have been obtained resembling some of the figures given by Gümbel in his 'Illustrations' of the forms met with by him in the Laurentian rocks of Bavaria.

In decalcifying by means of a dilute acid some of the specimens from Côte St. Pierre, placed in his hands in 1864–65, Dr. Carpenter found that the action of the acid was arrested at certain portions of the skeleton, presenting a yellowish-brown surface; and he showed me, two or three weeks ago, that in a specimen recently given him, from the same locality, considerable portions of the general form remained undissolved by such an acid. On partially reducing some of these portions to a powder, however, we immediately observed effervescence by the dilute acid; and strong acid produced it without bruising. There is little doubt that these portions of the skeleton are partially replaced by dolomite, as more recent fossils are often known to be, of which there is a noted instance in the Trenton limestone of Ottawa. But the circumstance is alluded to for the purpose of comparing these dolomitized portions of the skeleton with the specimens from Burgess, in which the replacement of the septal layers by dolomite appears to be the general condition. In such of these specimens as have been examined the minute structure seems to be wholly, or almost wholly, destroyed; but it is probable that upon a further investigation of the locality some spots will be found to yield specimens in which the calcareous skeleton still exists unreplaced by dolomite; and I may safely venture to predict that in such specimens the minute structure, in respect both to canals and tubuli, will be found as well preserved as in any of the specimens from Côte St. Pierre.

It was the general form on weathered surfaces, and its strong resemblance to *Stromatopora*, which first attracted my attention to *Eozoon;* and the persistence of it in two distinct minerals, pyroxene and loganite, emboldened me, in 1857, to place before the Meeting of the American Association for the Advancement of Science specimens of it as probably a Laurentian fossil. After that, the form was found preserved in a third mineral, serpentine; and in one of the previous specimens it was then observed to pass continuously through two of the minerals, pyroxene and serpentine. Now we have it imbedded in limestone, just as most fossils are. In every case, with the exception of the Burgess specimens, the general form is composed of carbonate of lime; and we have good grounds for supposing it was originally so in the Burgess specimens also. If, therefore, with such evidence, and without the minute structure, I was, upon a calculation of chances, disposed, in 1857, to look upon the form as organic, much more must I so regard it when the chances have been so much augmented by the subsequent accumulation of evidence of the same kind, and the addition of the minute structure, as described by Dr. Dawson, whose observations have been confirmed and added to by the highest British authority upon the class of animals to which the form has been referred, leaving in my mind no room whatever for doubt of its organic character. Objections to it as an organism have been made by Professors King and Rowney; but these appear to me to be based upon the supposition that because some parts simulating organic structure are undoubtedly mere mineral arrangement, therefore all parts are mineral. Dr. Dawson has not proceeded upon the opposite supposition, that because some parts are, in his opinion, undoubtedly organic, therefore all parts stimulating organic structure are organic; but he has carefully distinguished between the mineral and organic arrangements. I am aware, from having supplied him with a vast number of specimens prepared for the microscsope by the lapidary of the Canadian Survey, from a series of rocks of Silurian and Huronian, as well as Laurentian age, and from having followed the course of his investigation as it proceeded, that nearly all the points of objection of Messrs. King and Rowney passed in review before him prior to his coming to the conclusions which he has published; and his reply to these objections forms a part of the succeeding paper.

Ascending Section of the Laurentian Rocks in the County of Hastings, Ontario. By Mr. H. G. Vennor.

	Feet.
1. Reddish and flesh-coloured granitic gneiss, the thickness of which is unknown; estimated at not less than	2,000
2. Greyish and flesh-coloured gneiss, sometimes hornblendic, passing towards the summit into a dark mica-schist, and including portions of greenish-white diorite; mean of several pretty closely agreeing measurements	10,400

3. Crystalline limestone, sometimes magnesian, including lenticular patches of quartz, and broken and contorted layers of quartzo-felspathic rock, rarely above a few inches in thickness. This limestone, which includes in Elzivir a one-foot bed of graphite, is sometimes very thin, but in other places attains a thickness of 750 feet; estimated as averaging.................. 400

4. Hornblendic and dioritic rocks, massive or schistose, occasionally associated near the base with dark micaceous schists, and also with chloritic and epidotic rocks, including beds of magnetite; average thickness.................................. 4,200

5. Crystalline and somewhat granular magnesian limestone, occasionally interstratified with diorites, and near the base with silicious slates and small beds of impure steatite.......... 330

This limestone, which is often siliceous and ferruginous, is metalliferous, holding disseminated copper pyrites, blende, mispickel, and iron pyrites, the latter also sometimes in beds of two or three feet. Gold occur in the limestone at the village of Madoc, associated with an argentiferous grey copper ore, and in irregular veins with bitter-spar, quartz, and a carbonaceous matter at the Richardson mine in Madoc.

6. Grey silicious or fine-grained mica-slates, with an interstratified mass of about sixty feet of yellowish-white dolomite divided into beds by thin layers of the mica-slate, which, as well as the dolomite, often becomes conglomerate, including rounded masses of gneiss and quartzite from one to twelve inches in diameter.... 400

7. Bluish and greyish micaceous slate, interstratified with layers of gneiss, and occasionally holding crystals of magnetite. The whole division weathers to a rusty brown................ 500

8. Gneissoid micaceous quartzites, banded grey and white, with a few instratified beds of silicious limestone, and, like the last division, weathering rusty brown...... 1,900

9. Grey micaceous limestone, sometimes plumbaginous, becoming on its upper portion a calc-schist, but more massive towards the base, where it is interstratified with occasional layers of diorite, and layers of a rusty-weathering gneiss like 8........... 1,000

This division in Tudor is traversed by numerous N W. and S.E. veins, holding galena in a gangue of calcite and barytine. The Eozoon from Tudor here described was obtained from about the middle of this calcareous division, which appears to form the summit of the Hastings series.

* Total thickness......... 21,130

*In explanation of the apparent discrepancies between the above section and the one given in the *Quarterly Journal of the Geological Society*, it is to be said that 8 and 9 of the latter section are repetitions of 1 and 2 on the other side of a synclinal, and that 2 in that section represents but a small exposed portion of the great mass of 8, whose measured thickness, as there stated, is 15,000 feet, and includes divisions 2, 3, and 4 of the present section.—EDS.

ON EOZOON CANADENSE.*

By J. W. Dawson, LL.D., F.R.S., F.G.S. With Notes by W. B. Carpenter, M.D., F.R.S.

I. SPECIMEN OF EOZOON FROM TUDOR, ONTARIO.

This very interesting specimen, submitted to me for examination by Sir. W. E. Logan, is, in my opinion, of great importance, as furnishing a conclusive answer to all those objections to the organic nature of *Eozoon* which have been founded on comparisons of its structures with the forms of fibrous, dendritic, or concretionary minerals,—objections which, however plausible in the case of highly crystalline rocks, in which organic remains may be simulated by merely mineral appearances readily confounded with them, are wholly inapplicable to the present specimen.

1. General appearance.—The fossil is of a clavate form, six and a half inches in length, and about four inches broad. It is contained in a slab of dark-colored, coarse, laminated limestone, holding sand, scales of mica, and minute grains and fibres of carbonaceous matter. The surface of the slab shows a weathered section of the fossil (Pl. II.); and the thickness remaining in the matrix is scarcely two lines, at least in the part exposed. The septa, or plates of the fossil, are in the state of white carbonate of lime, which shows their form and arrangement very distinctly, in contrast to the dark stone filling the chambers. The specimen lies flat in the plane of stratification, and has probably suffered some compression. Its septa are convex towards the broad end, and somewhat undulating. In some places they are continuous half-way across the specimen; in other places they divide and re-unite at short distances. A few transverse plates, or connecting columns, are visible; and there are also a number of small veins or cracks passing nearly at right angles to the septa, and filled with carbonate of lime, similar in general appearance to the septa themselves.

On one side, the outline of the fossil is well preserved. The narrow end, which I regard as the basal portion, is rounded. The outline of the side first bends inward, and then outward, forming a graceful double curve, which extends along the greater part of the length. Above this is an abrupt projection, and then a sudden

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* From the Quar. Jour. Geol. Soc., Aug. 1867. Read before the Geological Society, May 8, 1867.

narrowing; and in the middle of the narrow portion, a part has the chambers obliterated by a white patch of carbonate of lime, below which some of the septa are bent downward in the middle. This is probably an effect of mechanical injury, or of the interference of a calc-spar vein.

With the exception of the upper part above referred to, the septa are seen to curve downward rapidly toward the margin, and to coalesce into a lateral wall, which forms the defined edge or limit of the fossil, and in which there are some indications of lateral orifices opening into the chambers. It is worthy of remark that, in this respect, the present specimen corresponds exactly with that which was originally figured by Sir W. E. Logan in the 'Geology of Canada,' p. 49, and which is the only other specimen that exhibited the lateral limit of the form.

On the side next the matrix, the septa terminate in blunt edges, and do not coalesce; as if the organism had been attached by that surface, or had been broken before being imbedded.

2. Microscopic characters.—Under the microscope, with a low power, the margins of the septa appear uneven, as if eroded or tending to an acervuline mode of growth; but occasionally the septa show a distinct and regular margin. For the most part merely traces of structure are presented, consisting of small parts of canals, filled with the dark colouring-matter of the limestone. In a few places (Pl. III. fig. 1), however, these appear as distinct bundles, similar to those in the Grenville specimens, but of fine texture.

[In fig. 2 is represented a portion of the canal-system in a Grenville specimen, in which the canals, which are transparent in one side (being infiltrated with carbonate of lime only) are seen on the other to be partially filled with black matter, probably a carbonaceous residuum of the sarcode which they originally contained.—W. B. C.]

In a few rare instances only can I detect, with a higher power, in the margin of some of the septa, traces of the fine tubulation characteristic of the proper chamber wall of *Eozoon*. For the most part this seems to have been obliterated by the infiltration of the tubuli with colourless carbonate of lime, similar to that of the skeleton.

In comparing the structure of this specimen with that of those found elsewhere, it would appear that the chambers are more continuous, and wider in proportion to the thickness of the septa, and that the canal-system is more delicate and indistinct than usual.

In the two former respects the specimens from the Calumet and from Burgess approach that now under consideration more nearly than do those from Grenville and Petite Nation; but it would be easy, even in the latter, to find occasional instances of a proportion of parts similar to that in the present example. General form is of little value as a character in such organisms; and so far as can be ascertained, this may have been the same in the present specimen and in that originally obtained from the Calumet, while in the specimens from Grenville a massive and aggregative mode of growth seems to have obliterated all distinctness of individual shape. Without additional specimens, and in the case of creatures so variable as the Foraminifera, it would be rash to decide whether the differences above noticed are of specific value, or depend on age, variability, or state of preservation. For this reason I refer the specimen for the present to *Eozoon Canadense*, merely distinguishing it as the Tudor variety.

From the state of preservation of the fossil, there are no crystalline structures present which can mislead any ordinarily skilful microscopist, except the minute veins of calcareous spar traversing the septa, and the cleavage-planes which have been developed in some portions of the latter.

I would remark that, as it seemed desirable not to injure any more than was absolutely necessary a unique and very valuable specimen, my observations of the microscopic structure have been made on a few slices of small size,—and that, as the microscopic structures are nearly the same in kind with those of specimens figured in former papers, I have not thought it necessary to prepare numerous drawings of them; while the admirable photograph executed for Sir W. E. Logan by Mr. Notman illustrates sufficiently the general form and arrangement of parts (see Pl. II.).

3. Concluding remarks.—In a letter to Dr. Carpenter, quoted by him in the 'Quarterly Journal of the Geological Society' for August 1866, p. 228, I referred to the occurrence of *Eozoon* preserved simply in carbonate of lime. The specimens which enabled me to make that statement were obtained at Madoc, near Tudor, this region being one in which the Laurentian rocks of Canada appear to be less highly metamorphosed than is usual. The specimens from Madoc, however, were mere fragments, imbedded in the limestone, and incapable of showing the general form. I may explain, in reference to this, that long practice in the examination of these limestones has enabled me to detect the smallest

fragments of *Eozoon* when present, and that in this way I had ascertained the existence of this fossil in one of the limestones of Madoc before the discovery of the fine specimen now under consideration.

I am disposed to regard the present specimen as a young individual, broken from its attachment and imbedded in a sandy calcareous mud. Its discovery affords the hope that the comparatively unaltered sediments in which it has been preserved, and which also contain the worm-burrows described by me in the 'Quarterly Journal of the Geological Society' for November,* will hereafter still more largely illustrate the Laurentian fauna.

II. SPECIMENS FROM LONG LAKE AND WENTWORTH.

Specimens from Long Lake, in the collection of the Geological Survey of Canada, exhibit white crystalline limestone with light-green compact or septariiform† serpentine, and much resemble some of the serpentine-limestones of Grenville. Under the microscope the calcareous matter presents a delicate areolated appearance, without lamination; but it is not an example of acervuline *Eozoon*, but rather of fragments of such a structure, confusedly aggregated together, and having the interstices and cell-cavities filled with serpentine. I have not found in any of these fragments a canal-system similar to that of *Eozoon Canadense*, though there are casts of large stolons, and, under a high power, the calcareous matter shows in many places the peculiar granular or cellular appearance which is one of the characters of the supplemental skeleton of that species. In a few places a tubulated cell-wall is preserved, with structure similar to that of *Eozoon Canadense*.

Specimens of Laurentian limestone from Wentworth, in the collection of the Geological Survey, exhibit many rounded siliceous bodies, some of which are apparently grains of sand, or small pebbles; but others, especially when freed from the calcareous matter by a dilute acid, appear as rounded bodies, with rough surfaces, either separate or aggregated in lines or groups, and having minute vermicular processes projecting from their surfaces (Pl. III. fig. 3). At first sight these suggest the idea of spicules;

* Vol. xxii. p. 608.

† I use the term 'septariiform' to denote the *curdled* appearance so often presented by the Laurentian serpentine.

but I think it on the whole more likely that they are casts of cavities and tubes belonging to some calcareous Foraminiferal organism which has disappeared. Similar bodies, found in the limestone of Bavaria, have been described by Gümbel, who interprets them in the same way.* They may also be compared with the silicious bodies mentioned in a former paper as occurring in the Loganite filling the chambers of specimens of *Eozoon* from Burgess.

III. SPECIMENS FROM MADOC.

I have already referred to fragments of *Eozoon* occurring in the limestone at Madoc, one of which, found several years ago, I did not then venture to describe as a fossil. It projected from the surface of the limestone, being composed of a yellowish dolomite, and looking like a fragment of a thick shell. When sliced, it presents interiorly a crystalline dolomite, limited and separated from the enclosing rock by a thin wall having a granular or porous structure and excavated into rounded recesses in the manner of *Eozoon*. It lies obliquely to the bedding, and evidently represents a hollow flattened calcareous wall filled by infiltration. The limestone which afforded this form was near the beds holding the worm-burrows described in the Society's Journal for November, 1866.

[A thin section of this body, carefully examined microscopically, presents numerous and very characteristic examples of the canal. system of *Eozoon*, exhibiting both the large widely branching systems of canals and the smaller and more penicillate tufts (Pl. III. figs. 4, 5) shown in the most perfect of the serpentinous specimens—but with this difference, that the canals, being filled with a material either identical with or very similar to that of the substance in which they are excavated, are so transparent as only to be brought into view by careful management of the light. —W. B. C.]

IV. OBJECTIONS TO THE ORGANIC NATURE OF EOZOON.

The discovery of the specimen from Tudor, above described, may appear to render unnecessary any reference to the elaborate attempt made by Profs. King and Rowney to explain the structures of *Eozoon* by a comparison with the forms of fibrous and

* Proceedings of Royal Academy of Munich, 1866; Q. J. G. S. vol. xxii. pt. i. p. 185 *et seq.*; also, Can. Naturalist, vol. iii. p. 81.

† Quart. Journ. Geol. Soc. vol. xxii. pt. ii. p. 23.

dendritic minerals,* more especially as Dr. Carpenter has already shown their inaccuracy in many important points. I think, however, that it may serve a useful purpose shortly to point out the more essential respects in which this comparison fails with regard to the Canadian specimens—with the view of relieving the discussion from matters irrelevant to it, and of fixing more exactly the limits of crystalline and organic forms in the serpentine-limestones and similar rocks.

The fundamental error of Messrs. King and Rowney arises from defective observation—in failing to distinguish, in the Canadian limestones themselves, between organic and crystalline forms. This is naturally followed by the identification of all these forms, whether mineral or organic, with a variety of purely crystalline arrangements occurring in other rocks, leading to their attaching the term 'Eozoonal' to any rock which shows any of the characters, whether mineral or organic, thus arbitrarily attached to the Canadian *Eozoon*. This is obviously a process by which the structure of any fossil might be proved to be a mere *lusus naturæ*.

A notable illustration of this is afforded by their regarding the veins of fibrous serpentine, or chrysotile, which occur in the Canadian specimens, as identical with the tubulated cell-wall of *Eozoon* —although they admit that these veins traverse all the structures indifferently and do not conform to the walls of the chambers. But any microscopist who possesses specimens of *Eozoon* containing these chrysotile veins may readily satisfy himself that, under a high power, they resolve themselves into *prismatic crystals in immediate contact with each other;* whereas, under a similar power, the true cell-wall is seen to consist of *slender, undulating, rounded threads of serpentine, penetrating a matrix of carbonate of lime.* Under polarized light, more especially, the difference is conspicuously apparent. It is true that, in many specimens and parts of specimens, the cell-wall of *Eozoon* is badly preserved and fails to show its structure; but in no instance does it present the appearance of chrysotile, or of any other fibrous mineral, when examined with care under sufficiently high powers. In my original examination of Sir William Logan's specimens from Grenville and the Calumet, I did not detect the finely tubulated cell-wall, which is very imperfectly preserved in those specimens; but the veins of

* I do not include here the 'septariiform' structure referred to above, which is common in the Canadian serpentine and has no connexion with the forms of the chambers.

fibrous serpentine were well known to me; and when Dr. Carpenter discovered the tubulation of the cell-wall in the specimens from Petite Nation, I compared this structure with that of these veins, and satisfied myself of its distinctness before acceding to his conclusions on this point.

It would also appear that the radiating and sheaf-like bundles of crystals of tremolite, or similar prismatic minerals. which occur in the Canadian serpentines, and also abound in those of Connemara, have been confounded with the tubulation of *Eozoon*; but these crystals have no definite relation to the forms of that fossil, and often occur where these are entirely absent; and in any case they are distinguished by their straight prismatic shape and their angular divergence from each other. Much use has also been made of the amorphous masses of opaque serpentinous matter which appear in some parts of the structure of *Eozoon*. These I regard as, in most cases, simply results of alteration or defective preservation, though they might also arise from the presence of foreign matters in the chambers, or from an incrustation of mineral matter before the final filling up of the cells. Generally their forms are purely inorganic; but in some cases they retain indications of the structures of *Eozoon*.

With reference to the canal-system of *Eozoon*, no value can be attached to loose comparisons of a structure so definite with the forms of dendritic silver and the filaments of moss-agates; still less can any resemblance be established between the canal-system and vermicular crystals of mica. These occur abundantly in some serpentines from the Calumet, and might readily be mistaken for organic forms; but their rhombic or hexagonal outline when seen in cross section, their transverse cleavage planes, and their want of any definite arrangement or relation to any general organic form, are sufficient to undeceive any practised observer. I have not seen specimens of the metaxite from Reichenstein referred to by Messrs. King and Rowney; but it is evident, from the description and figure given of it, that, whether organic or otherwise, it is not similar to the canals of *Eozoon Canadense*. But all these and similar comparisons are evidently worthless when it is considered that they have to account for definite, ramifying, cylindrical forms, penetrating a skeleton or matrix of limestone, which has itself a definite arrangement and structure, and, further, when we find that these forms are represented by substances so diverse as serpentine, pyroxene, limestone, and carbonaceous matter.

This is intelligible on the supposition of tubes filled with foreign matters, but not on that of dendritic crystallization.

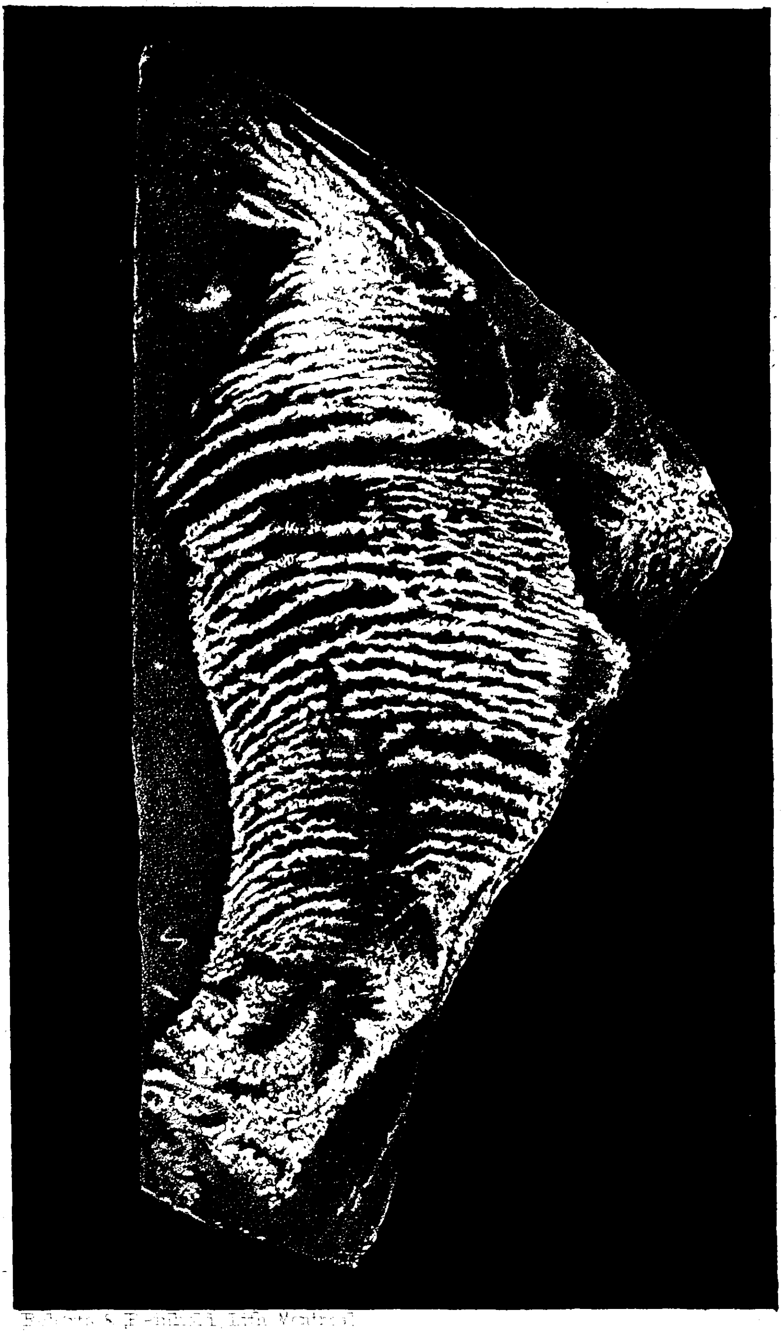
If all specimens of *Eozoon* were of the acervuline character, the comparisons of the chamber-casts with concretionary granules might have some plausibility. But it is to be observed that the laminated arrangement is the typical one; and the study of the larger specimens, cut under the direction of Sir W. E. Logan, shows that these laminated forms must have grown on certain strata-planes before the deposition of the overlying beds, and that the beds are, in part, composed of the broken fragments of similar laminated structures. Further, much of the apparently acervuline *Eozoon* rock is composed of such broken fragments, the interstices between which should not be confounded with the chambers; while the fact that the serpentine fills such interstices as well as the chambers shows that its arrangement is not concretionary.* Again, these chambers are filled in different specimens with serpentine, pyroxene, loganite, calcareous spar, chondrodite, or even with arenaceous limestone. It is also to be observed that the examination of a number of limestones, other than Canadian, by Messrs. King and Rowney, has obliged them to admit that the laminated forms in combination with the canal-system are 'essentially Canadian,' and that the only instances of structures clearly resembling the Canadian specimens are afforded by limestones Laurentian in age, and in some of which (as, for instance, in those of Bavaria and Scandinavia) Carpenter and Gümbel have actually found the structure of *Eozoon*. The other serpentine-limestones examined (for example, that of Skye) are admitted to fail in essential points of structure; and the only serpentine believed to be of eruptive origin examined by them is confessedly destitute of all semblance of *Eozoon*. Similar results have been attained by the more careful researches of Prof. Gümbel, whose paper is well deserving of study by all who have any doubts on this subject.

In the above remarks I have not referred to the disputed case of the Connemara limestones; but I may state that I have not been able to satisfy myself of the occurrence of the structures of *Eozoon* in such specimens as I have had the opportunity to examine.* It is perhaps necessary to add that there exists in

* Such Irish specimens of serpentine limestone as I have seen, appear much more highly crystalline than the beds in Canada which contain *Eozoon*.

Canada abundance of Laurentian limestone which shows no indication of the structures of *Eözoon*. In some cases it is evident that such structures have not been present. In other cases they may have been obliterated by processes of crystallization. As in the case of other fossils, it is only in certain beds, and in certain parts of those beds, that well-characterized specimens can be found. I may also repeat here that in the original examination of *Eozoon*, in the spring of 1864, I was furnished by Sir W. E. Logan with specimens of all these limestones, and also with serpentine-limestones of Silurian age, and that, while all possible care was taken to compare these with the specimens of *Eozoon*, it was not thought necessary to publish notices of the crystalline and concretionary forms observed, many of which were very curious and might afford materials for other papers of the nature of that criticised in the above remarks.

[The examination of a large number of sections of a specimen of *Eozoon*, recently placed in my hands by Sir William Logan, in which the canal-system is extraordinarily well preserved, enables me to supply a most unexpected confirmation of Dr. Dawson's statements in regard to the occurrence of dendritic and other forms of this system, which cannot be accounted for by the intrusion of any foreign mineral; for many parts of the calcareous lamellæ in these sections, which, when viewed by ordinary transmitted light, appear quite homogeneous and structureless, are found, when the light is reduced by Collin's 'graduating diaphragm,' to exhibit a most beautiful development of various forms of canal-system (often resembling those of Dr. Dawson's Madoc specimen represented in Pl. III. figs. 4, 5), which cross the cleavage-planes of the shell-substance in every direction. Now these parts, when subjected to decalcification, show no trace of canal-system; so that it is obvious, both from their optical and from their chemical reactions, that the substance filling the canals must have been *carbonate of lime*, which has thus completely solidified the shell layer, having been deposited in the canals previously excavated in its interior, just as crystalline carbonate of lime fills up the reticular spaces of the skeleton of Echinodermata fossilized in a calcareous matrix. This fact affords conclusive evidence of *organic structure*, since no conceivable process of crystallization could give origin to dendritic extensions of carbonate of lime disposed on exactly the same crystalline system with the calcite which includes it, the two substances being



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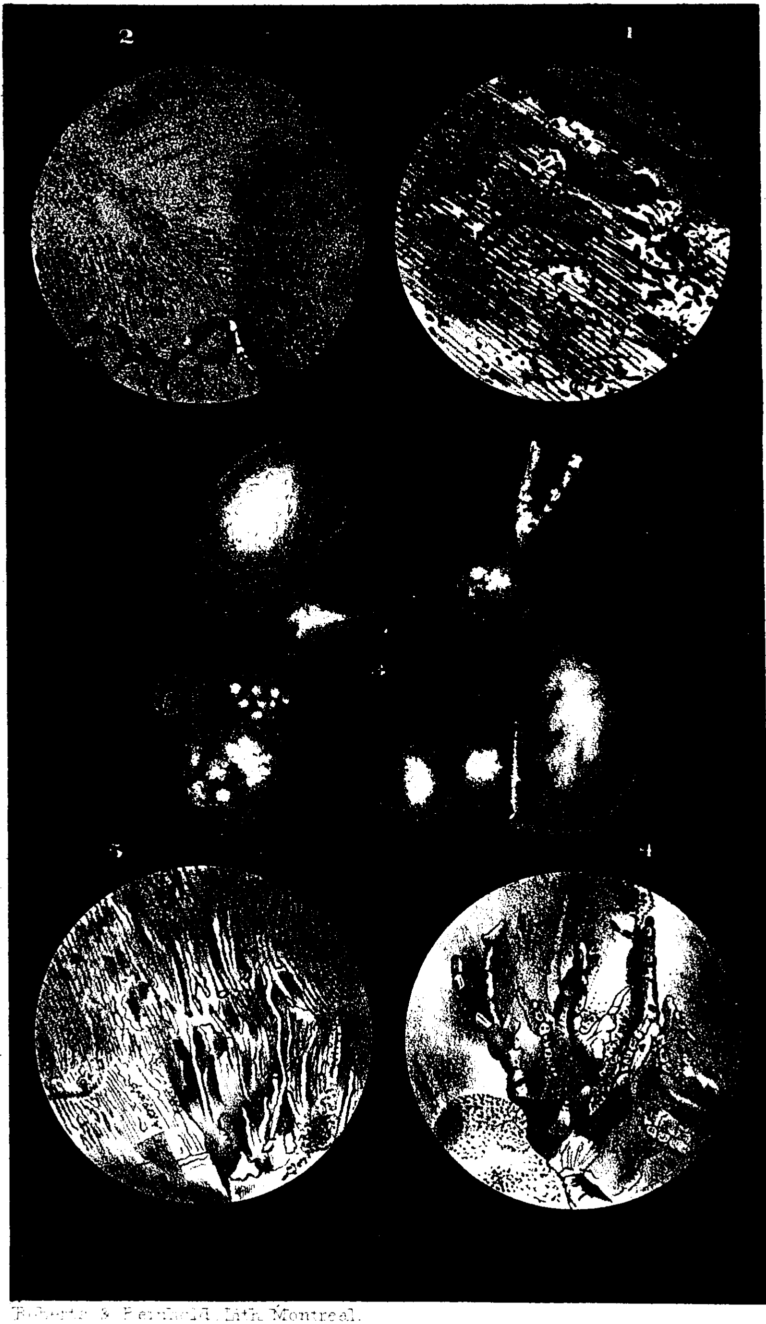
EOZOON CANADENSE



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EOZOON CANADENSE.

mineralogically homogeneous, and only structurally distinguishable by the effect of their junction-surfaces on the course of faint rays of light transmitted, through them.—W. B. C.]

Explanation of the Plates.

Plate II.

Specimen of *Eozoon Canadense*, imbedded in a dark-coloured homogeneous limestone, occurring in the Lower Laurentian series in Tudor, Ontario; two-thirds of the natural size.

Plate III.

Fig. 1. Section of one of the calcareous layers of the Tudor specimen (Plate II.), showing canal-system imperfectly infiltrated with black (carbonaceous?) matter; magnified 120 diameters.

2. Section of the shelly layer of a specimen of *Eozoon* from Grenville, showing a minute form of canal-system, partly injected with black matter and partly with serpentine; magnified 120 diameters.

3. Siliceous bodies (internal casts?) from a specimen of *Eozoon* from Wentworth; magnified 50 diameters.

4, 5. Sections of a fragment of *Eozoon* from the Madoc limestone, showing various forms of canal-system filled with carbonate of lime; magnified 120 diameters.

MISCELLANEOUS.

NOTE ON SUPPOSED BURROWS OF WORMS IN THE LAURENTIAN ROCKS OF CANADA.

By J. W. Dawson, LL.D., F.R.S., &c.

Among other indications of fossils in the Laurentian rocks, mentioned in my paper on the structure of Eozoon, are certain perforations resembling burrows of worms, found in a calcareous quartzite or impure limestone from Madoc, in Upper Canada. They occur in specimens in the Museum of the Geological Surv[illegible], and also in specimens subsequently collected by myself at the same place.

The beds at Madoc, containing these impressions, underlie, unconformably, the Lower Silurian limestones, and are regarded by Sir W. E. Logan as belonging to a somewhat higher horizon in the Laurentian, than the Eozoon Serpentines of Grenville. They are also less highly metamorphosed than the Laurentian rocks generrally. They are described in Sir W. E. Logan's Report on the Geology of Canada, 1863, at p. 32.

The impressions referred to consist of perforations approaching to a cylindrical form, and filled with rounded siliceous sand, more or less stained with carbonaceous and ferruginous matter, more especially near the circumference of the cylinders. These superficial portions being harder than the containing rock, and of darker colour, and also harder than the interior of the cylinders, project as black rings from the weathered surfaces; but in their continuation into the interior of the mass, they appear only as spots or lines of a slightly darker colour, or stained with iron-rust.

When sliced transversely and examined under the microscope, they appear as round, oval, or semicircular holes drilled through the rock, and lined around their circumference with dense and dark-coloured siliceous matter, while the axis, which is often of a bilobate form, is comparatively transparent and of softer texture. The perforations are often at right angles to the bedding, but in some cases nearly parallel with it.

In regard to the origin of these perforations, I suppose that they may have been either (1) burrows of worms filled with sand subsequently hardened and stained at the surface, or (2) tubes composed of sand, like those of Sabella, or (3) cavities left by the decay of Algæ and filled with sand. The first I think the most probable view.

I may add that the beds at Madoc, containing these supposed fossils, hold also, on their weathered surfaces, impressions with rude casts of concentric laminæ like those of Stromapotora or Eozoon, but too obscure for determination. The limestones interstratified with these beds also contain fragments of Eozoon not fossilized by serpentine but simply by carbonate of lime, carbonaceous fibres, spicules like those of sponges, and lenticular bodies of unknown nature. - *Journal of the Geological Society of London.*

OBITUARY.

The Right Honourable Sir EDMUND HEAD, Bart., K.C.B., LL.D., F.R.S., &c.

By the sudden death of the able and patriotic man whose name stands at the head of this article, Canada loses one of the few statesmen in the mother country interested in her welfare, and having influence to make their good wishes effectual. Sir Edmund, after a brilliant career at Oriel College, Oxford, where he took a first-class, and afterwards a fellowship, entered into educational and literary pursuits as a tutor of Mereton College and a writer of articles in the Reviews. Having attracted attention by the ability displayed in the latter, he was appointed an Assistant Poor Law Commissioner, and subsequently Chief Commissioner. On the reconstruction of the Poor Law Board in 1847, he received the government of New Brunswick, and in 1854 was promoted to be the Governor-General of Canada, from which office he retired in 1861.

Both in New Brunswick and Canada Sir Edmund was, as might have been expected, conspicuous as a patron of education, literature, and science; and was remarkable, not only for his readiness to give his countenance to every worthy undertaking, but for the judicious advice which he gave, and his willingness to devote time and thought to the consideration of the best means for advancing the interests in view.

In New Brunswick he more especially took a warm interest in the Provincial University, then in a languishing condition; and procured the appointment of a Commission to inquire into its deficiencies and difficulties, and the means for their remedy. The labours of this Commission (which consisted of the Honble. J. H. Gray of New Brunswick, Rev. Dr. Ryerson, Principal Dawson--then Superintendent of Education in Nova Scotia,—and the Honbles. J. H. Saunders and James Brown of New Brunswick) resulted in the preparation of a scheme which, if fully carried out, would have placed New Brunswick far in advance of the other colonies in this respect. Sir Edmund was, however, soon after removed to Canada, and the plan devised was only partially acted on; but it has already given a new stimulus to higher education in New Brunswick, and has resulted in placing the University in a very satisfactory condition.

In Canada, though checked by the unsettled condition of political affairs and by the want of sympathy with his large views on the part of most of our public men, Sir Edmund did much for the promotion of his own favourite pursuits and for laying the foundation of a high educational culture. The educational measures adopted during his administration all more or less bore the impress of his mind, and the various Scientific and Literary Societies, and the Geological Survey, owe much to his personal influence. In this community, the McGill University, the

Natural History Society, and the Normal Schools, specially owe him a debt of gratitude.

While in Canada he met with the most severe calamity of his life, the death, by drowning, of his only son, a young man of excellent parts, who had already made much progress in scientific attainments, and who bade fair to follow in the footsteps of his father.

Sir Edmund's largest literary work was his "Handbook of Spanish Painting." He also published a clever little book on "Shall and Will," and an important memoir on the celebrated "Temple of Serapis at Pozzuoli," in which he brings his classical and antiquarian lore to aid the geologist in explaining the wonderful alternations of elevation and subsidence to which this building and the neighbouring coast have been subjected.

Sir Edmund died suddenly at his town residence, Eaton Square, London, on the 25th of January, 1868.

Published, Montreal, May 24, 1868.