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THE

CANADIAN NATURALIST.

SECOND SERIES.

CONTRIBUTIONS TO LITHOLOGY.*

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III. On Some Eruptive Rocks.†

In Silliman's Journal for March 1860 (2nd, xxix, 282) there is a short note, pointing out the existence, in the vicinity of Montreal, of several interesting classes of eruptive rocks, including quartziferous porphyries, trachytes, phonolite, dolerites, and diorites. It is proposed in the third part of the present paper to describe the results of some chemical and mineralogical examinations of these rocks, and to give by way of preface a description of their geographical distribution and geological relations. They may be considered geographically as belonging to two groups; of which the first and more important for the number and variety of its rocks may be conveniently described as the Montreal group. It consists of a succession of intrusive masses along a belt running nearly transverse to the undulations of the Notre Dame Mountains, which are the prolongation of the Appalachians into eastern Canada. Commencing at Shefford Mountain, an isolated trachytic mass not far removed from the western base of the Notre Dame range, we find, going westward, the detached hills known as Yamaska, Rougemont, Rouville or Belœil, Montarville or Boucherville, Mount Royal or Montreal, and Rigaud Mountains; the last being distant about ninety miles from Shefford. Brome Mountain, which

* Concluded from page 36.

† From *Silliman's Journal*, vol. xxxviii.

occupies a large area to the south of Shefford, approaches within two miles of it. In like manner, a few miles to the south of Belœil is another intrusive mass known as Mount Johnson or Monnoir; making in all nine hills of eruptive rock belonging to the Montreal group. Besides these, numerous smaller intrusive masses in the form of dykes are met with around and between the hills. From Mount Royal to Rigaud Mountain, a distance of about thirty miles, a gentle undulation of the strata is observed, which increases to the westward of Rigaud, and finally gives place to a considerable fault. This disturbance has been traced to the Laurentide hills on the Lac des Chats, 140 miles west of Montreal; but to the eastward the strata exhibit no evidence of this transverse undulation, unless the appearance of the intrusive rocks already mentioned be supposed to indicate the prolongation of a fracture without sensible dislocation.

The whole of these eruptive rocks rise through unaltered paleozoic strata, which however, in the immediate vicinity of the intrusive rocks, exhibit a local metamorphism. The hills of Shefford, Brome, and Yamaska break through the strata of the Quebec group, and lie a little to the east of the great line of dislocation which, in this region, brings up the lower members of the paleozoic series against the superior portion of the Lower Silurian, and divides into two districts the great paleozoic basin. (Geology of Canada, pp. 234, 597.) The other hills all belong to the western division of this basin, and break through various members of the Lower Silurian series from the Potsdam to the Hudson River formation. Among the numerous dykes which traverse not only the sedimentary strata but the intrusive masses, there are some which intersect the conglomerates of St. Helen's Island. These are of uncertain age, but repose unconformably on the Lower Silurian series, and enclose pebbles and masses of Upper Silurian limestone characterized by fossils of the Lower Helderberg period. (Ibid., p. 356.)

This group of intrusive rocks offers very great varieties in composition; thus Shefford and Brome consist of what we shall describe as a granitoid trachyte, while the succeeding mountain, Yamaska, and the most western, Rigaud, both consist in part of a kind of trachyte, and in part of diorite. Monnoir and Belœil also consist of diorites, which however differ from the last two, and from each other; while Rougemont, Montarville, and Mount Royal consist in great part of dolerites, presenting however many varieties in composition, and sometimes passing into pyroxenite. The dolerites of Rougemont and Mount Royal are cut by dykes of trachyte. Similar dykes also traverse the diorite of Yamaska, and may perhaps be connected with the trachytic portion of this mountain. It is probable, judging from some specimens from Rougemont, that the dolerite is there intersected by veins of diorite, some of which resemble that of Belœil, and others that of Monnoir. Dykes both of trachyte, phonolite, and dolerite are also found traversing the Lower Silurian strata in the vicinity of the great eruptive masses; and the conglomerate of St. Helen's mentioned above is traversed by dykes of dolerite, which in their turn are cut by others of trachyte.

A second and smaller group of intrusive rocks occurs to the northwest of Montreal, chiefly in the county of Grenville, where they traverse the gneiss and limestones of the Laurentian system. The principal undulations of these rocks have, like those of the Appalachians, a north and south direction; but there is apparent also a second series of undulations, affecting in a less degree the geographical distribution of the strata, and having, like the Montreal and Rigaud undulation, an east and west direction. Coincident with the latter system of folds is a series of doleritic dykes, which nowhere attain a great breath, but have in some cases been traced more than fifty miles in a nearly east and west direction. These dykes are interrupted by a great mass of reddish syenite, passing in some parts into granite, and occupying an area of about thirty-six square miles in the townships of Grenville, Chatham, and Wentworth. Dykes of this syenite extend from the central mass, and traverse the surrounding gneiss and limestone. Numerous dykes of quartziferous porphyry intersect both this syenite and the surrounding gneiss, and are seen in one case to proceed from a considerable nucleus of porphyry, which rises into a small mountain; rendering it probable that numerous other porphyry dykes of the region radiate in like manner from other nuclei of the same rock. Some parts of this porphyry enclose fragments of syenite, dolerite, and gneiss, which vary in size from small grains to several feet in diameter, and often give to the rock the character of a breccia. In one instance a bed of gneiss, upwards of a hundred yards in length, is completely surrounded by the porphyry.

Orthophyre and Syenite.

Orthoclase-Porphyry or Orthophyre.—Under this head may be noticed a rock which has for its base a compact petrosilex, or intimate mixture of orthoclase and quartz, rendered porphyritic by the presence of grains or crystals of orthoclase, of quartz, or of both of these minerals together. The occurrence of this rock at Grenville, where it forms dykes in the syenite of that region, has just been noticed. The fine-grained petrosilicious base of this rock varies in color from dark green to various shades of red, purple, and black; these differences probably depending upon the degree of oxydation of the contained iron. Throughout this paste are disseminated well-defined crystals of a rose-red or flesh-red feldspar apparently orthoclase, sometimes very abundant; and less frequently small grains of nearly colorless translucent quartz. An analysis was made of a characteristic variety of the rock, the base of which was greenish-black, jasper-like, conchoidal in fracture, and feebly translucent on the edges, with a somewhat waxy lustre. The hardness was nearly equal to that of quartz, and the specific gravity 2.62. A few distinct crystals of red orthoclase, and some grains of quartz, were present. The base, freed as much as possible from these, gave as follows:

	I
Silica	72.20
Alumina	12.50
Peroxyd of iron	3.70
Lime	.90
Potash	3.88
Soda	5.30
Volatile	.60
	99.08

The oxygen ratio of the alkalies and alumina is 2.02: 5.84, or nearly 1:3. The alumina requires 43.80 parts of silica to form with the alkalies 65.48 parts of a feldspar having the ratios 1:3:12, which are those of orthoclase and albite. There will then remain 28.4 parts of silica. This, with the exception of a small amount which is probably united with the oxyd of iron and lime, may be regarded as uncombined. The porphyries of this region receive a high polish, and are sometimes very beautiful.

SYENITE.—The syenite of this region consists of orthoclase, usually flesh-red in color, and grayish vitreous quartz, with a small portion of blackish-green hornblende, which is sometimes almost or altogether wanting, and is occasionally accompanied with a little mica. The orthoclase is often nearly compact, but more genrally distinctly crystalline and cleavable, and so far as observed, is not associated with any triclinic feldspar. The hornblende is apparently subject to decomposition, becoming soft, earthy, and ferruginous in its aspect, while the feldspar retains its brilliancy. The partial analysis of such a specimen of the syenite gave only 0.56 of lime, and traces of magnesia, with 3.75 per cent. of peroxyd of iron, and of alkalies, potash 4.43, soda 4.35. This large proportion of soda is also to be remarked in the orthophyre just described, and in the red orthoclase-gneiss of this region, a portion of which gave 3.86 per cent of potash and 3.70 of soda; while the red orthoclase from the rocks of this Laurentian series, named perthite by Dr. Thompson, gives in like manner 6.37 of potash to 5.56 of soda. A nearly pure potash-orthoclase, generally white in color, is however found in some of the stratified Laurentian rocks. (Geology of Canada, page 474.)

This syenite of Grenville has in some portions undergone a peculiar decomposition, which has reduced it to a soft greenish matter having the aspect of serpentine, or rather of pyrallolite. This change has been remarked only in the vicinity of some remarkable veins of chert which are here found cutting the syenite, and as described by Sir W. E. Logan, is more or less complete for a distance of two hundred yards on each side of them. In specimens of this altered rock, the quartz remains unchanged; while the feldspar, still preserving its cleavages, has a hardness no greater than carbonate of lime. It is somewhat unctuous to the touch, with a feeble waxy lustre, and its color is occasionally reddish, but more often of a pale green. Such a specimen was selected for analysis and gave of silica 80.65, alumina 12.60, lime 0.60, soda and a little potash 2.65, volatile 2.10, magnesia and oxyd of iron, traces; = 98.60. From this result it appears that the feldspar of the syenite has lost nearly two thirds of its alkali; the iron and other bases having also for the most part disappeared. This removal of the protoxyd bases would appear from the character of the resulting mineral to be different from that which takes place during the kaolinization of feldspar. The nature of the process requires further investigation, but it was not improbably connected with the deposition of the adjacent chert or hornstone. This substance, according to Sir W. E. Logan, forms two large veins which cut the syenite vertically, and have a breadth of from four to seven feet. It is generally arranged in bands or layers parallel to the walls of the veins, and varying in color from white to yellowish and flesh-red. The mineral has the chemical characters of flint or buhrstone, and like the latter presents numerous irregular cells, the walls of which are sometimes incrusted with crystals of quartz, and in other cases bear the impression of small cubes, perhaps of crystals of fluor-spar, which have themselves disappeared. The relations of these singular veins of silex show that it cannot be of sedimentary origin, and it can scarcely be doubted that it is an aqueous deposit, and results from a similar process to that which on a lesser scale gives rise to agate and chalcedony in various rocks. (Geology of Canada, page 41.)

Trachytes.

Under this head we shall describe a class of rocks which are very abundant in Eastern Canada, and present a great variety of aspects. There are many dykes in the vicinity of Montreal which resemble some of the typical trachytic rocks of Auvergne and of the Rhine, while the rocks of the mountains of Brome and Shefford consist almost entirely of distinctly crystalline feldspar. These will be described as granitoid trachytes, under which head may also be included a somewhat similar rock from Yamaska Mountain.

Brome and Shefford Mountains.—The trachytes of Brome and Shefford occupy two considerable areas near to each other, and, as already stated, are the easternmost of the eruptive masses now under description. The larger area covers about twenty square miles in Brome and the western part of the township of Shefford. It consists of several rounded hills, of which the principal are named Brome and Shefford Mountains, and rise boldly about 1,000 feet above the surrounding plain. The rock shows divisional planes, giving it an aspect of stratification, and separates by other joints into rectangular blocks. The second area includes about nine square miles in the township of Shefford, to the northwest of the last, and at the nearest point is only about two miles removed from it. This is known as Shefford Mountain.

The rocks of these two mountainous areas present but very slight differences; being, so far as examined, everywhere made up in great part of a crystalline feldspar, with small portions of brownish-black mica, or of black hornblende, which are sometimes associated. The proportion of these two minerals is never above a few hundredths, and is often less than one hundredth. The other mineral species are small brilliant crystals of yellowish sphene, and others of magnetic iron, amounting together probably to one thousandth of the mass. In some finer-grained varieties a few rare crystals of sodalite and of nepheline are met with. But for the uniform absence of quartz, these rocks might be taken for varieties of granite and syenite. They are very friable, and subject to disintegration, so that the soil for some distance around these mountains is almost entirely made up of the separated crystals of feldspar; which however show but little tendency to decomposition, and retain their lustre. The rock is sometimes rather finely granular in its texture; but is often composed of cleavable masses of orthoclase, which are from one fifth to one half of an inch in breadth, and sometimes nearly an inch in length. The lustre is vitreous, and in the more opaque varieties, pearly; but the crystals never exhibit the eminently glassy lustre nor the fissured appearance that characterizes the feldspars of many European trachytes which are similar to them in composition. The color of the feldspar of these rocks is white, passing into reddish on the one hand, and into pearl-gray or lavender-gray on the other.

Specimens of the rock of Brome Mountain were taken from the side near to the village of West Shefford. It was coarsely crystalline, lavender-gray in color, and contained a little brown mica, sphene, and magnetic iron, but no hornblende. The density of fragments of the rock was found to be 2.632–2.638. Selected grains of the feldspar had a specific gravity of 2.575, and gave by analysis the result II. The analysis of a second specimen from another portion of the hill, is given under III.

The rock from the south side of Shefford Mountain was next examined. In one part it consisted of a coarse-grained grayish-white feldspar with a little black mica, and closely resembled the rock just described from the adjacent mountain. A little lower down the hill however was a variety which, though completely crystalline, was more coherent and finer-grained than that of Brome, the feldspar rarely exhibiting cleavage-planes more than a fourth of an inch in length. Brilliant crystalline grains of black hornblende about the size of grains of rice were sparingly disseminated through the mass, together with very small portions of magnetite and yellowish sphene. Fragments of the rock had a density of 2.607–2.657. The feldspar was yellowish-white and sub-translucent, with a somewhat pearly lustre. By crushing and washing the mass, the grains of feldspar were separated from the heavier minerals, and found to have a specific gravity of 2.561. The result of its analysis, which scarcely differs from that of Brome, is given under IV.

	II.	III.	IV.
Silica	65.70	65.30	65.15
Alumina	20.80	20.70	20.55
Lime	.84	.84	.73
Potash	6.43	....	6.39
Soda	6·52	....	6.67
Volatile	.50	....	.50
	100.79		99.99

YAMASKA MOUNTAIN.—About twelve miles to the north of west from Shefford Mountain rises the hill of intrusive rock known as Yamaska Mountain, which has an area of about four square miles, and breaks through the strata of the Quebec group, near the line of the great dislocation which brings these up against the limestones of the Trenton group. The southeastern part of this hill consists of a granitoid diorite hereafter to be noticed; but the greater portion of the mass may be described as a granitoid trachyte, differing in aspect from that of Brome and Shefford, in being somewhat more micaceous and more fissile. The mica, which is dark brown, is in elongated flakes, and there is neither hornblende nor quartz in the specimens collected, which however hold small portions of magnetite, and minute crystals of amber-yellow sphene. These seem to be contained in veins of segregation, which are of a lighter color than the mass. The cleavable feldspar grains, which make up by far the greater part of the rock, are brilliant, with a vitreous lustre, and are often yellowish or reddish-gray in color. A portion of this feldspar separated by washing from the crushed mass of the rock, had a specific gravity of 2·503, and gave by analysis the result V. Another portion of selected grains of the feldspar gave VI. Both specimens were however somewhat impure.

	V.	VI.
Silica	61.10	58.60
Alumina	20.10	21.60
Peroxyd of iron	2.90	2.88
Lime	3.65	5.40
Magnesia	.79	1.84
Potash	3.54	3.08
Soda	5.93	5.51
Volatile	.40	.80
	98.41	99.71

Besides these great trachytic hills, numerous smaller masses of different varieties of trachyte, in the form of dykes and beds, are found along the line of country between Rigaud and Yamaska Mountains. The diorite of the latter is cut into dykes of a white or brownish-gray trachyte, which is often porphyritic, and may be connected the great mass iust described.

CHAMBLY.—At Chambly a mass of porphyritic trachyte is intruded in the form of a bed among the strata of the Hudson River formation; and about midway in the Chambly canal a similar trachyte is met with, which contains in drusy cavities, crystals of quartz, calcite, analcime, and chabazite. The base of this rock is of a pale fawn color, and appears at first sight to be micaceous; but on closer examination it is seen to be almost entirely feldspathic. Minute portions of pyrites, and grains of magnetic iron, are rarely met with, and small scales of a dark green micaceous mineral are very sparsely disseminated. The crystals of orthoclase, which are very abundant, are sometimes an inch in length, and one fourth of an inch in thickness: they are more or less modified, and terminated at both ends. They are easily detached from the rock, and are yellowish and opaque on the exterior, but the inner portions of the large crystals are transparent and vitreous. The composition of the crystals is given under VII. The paste of this porphyry, when carefully freed from crystals, lost by ignition 2.1 per cent. When pulverized and digested with dilute nitric acid, it effervesced slightly, giving off carbonic acid, together with red fumes, arising in part from the oxydation of the pyrites. The portion thus dissolved equalled carbonate of lime 1.76, carbonate of magnesia 0.98, peroxyd of iron with a trace of alumina 2.12 per cent. The residue, dried at 300° F., gave the result VIII.

	VII.	VIII.
Silica	66.15	67.60
Alumina	19.75	18.30
Peroxyd of iron	....	1.40
Lime	.95	.45
Potash	7.53	5.10
Soda	5.19	5.85
Volatile	.55	.25
	100.12	99.85

The paste of this trachyte thus differs but little from the crystals in composition. It contains only a slight excess of silica, and seems to be made up of lamellæ of orthoclase, mingled with small portions of carbonates of lime and magnesia. A part of the iron also is probably present as carbonate, which, by its decomposition, gives rise to the rusty red color of the weathered surface of the trachyte.

MONTREAL.—The island of Montreal offers a great variety of trachytic rocks, which traverse both the Lower Silurian strata, and the dolerite of Mount Royal. Some of these dykes are finely granular, occasionally crumbling to sand, and frequently are earthy in texture. In some cases they assume a concretionary structure, and they are often porphyritic from the presence of feldspar or hornblende. One variety exhibits large feldspar crystals in a compact purplish or lavender-gray base, with a waxy lustre. This effervesces with acids, from an admixture of earthy carbonates, and closely resembles in its aspect certain trachytes from the Siebengebirge on the Rhine. Other varieties can scarcely be distinguished from the so-called domite, the trachyte of the Puy de Dôme, and exhibit small drusy cavities. The presence of carbonates in trachytic rocks has generally been overlooked; Deville however found seven per cent of carbonate of lime in a trachytic rock from Hungary, and it occurs disseminated in some of the trachytes of the Siebengebirge. Some of the trachytes about to be described contain moreover carbonates of magnesia and protoxyd of iron, and weather to some depth of a reddish-brown color from the peroxydation of the latter, like the trachyte from Chambly just noticed. Acids remove from many of these rocks, in addition to the carbonates, portions of alumina and alkalies. These are derived from a soluble silicate, which in the trachytes of Brome appears only as rare crystals of nepheline, and in Chambly as analcime and chabazite. In some of the compact and earthy varieties about Montreal, however, this soluble silicate exists to a large extent, and has the composition of natrolite. By this admixture of a zeolite the trachytes pass into phonolite.

The first of these trachytes which will be noticed forms a dyke near McGill College. The rock is divided by joints into irregular fragments, whose surfaces are often coated with thin-bladed crystals of an aluminous mineral, apparently zeolitic. Small brilliant crystals of cubic iron-pyrites, often highly modified, are disseminated through the mass. The rock has the hardness of feldspar, and a specific gravity of from 2.617 to 2.632. Its color is white, passing into bluish and grayish-white; it has a feebly shining lustre, and is slightly translucent on the edges, with a compact or finely granular texture, and an uneven sub-conchoidal fracture. Before the blow-pipe it fuses with intumescence into a white enamel. The rock in powder, is attacked even by acetic acid, which removes 0.8 per cent of carbonate of lime, besides 1.5 per cent of alumina and oxyd of iron; the latter apparently derived from a carbonate. Nitric acid dissolves a little more lime, oxydizes the pyrites, and takes up, besides alumina and alkalies, a considerable portion of manganese. This apparently exists in the form of sulphuret, since, while it is soluble in dilute nitric acid, the white portions of the rock afford no trace of manganese before the blow-pipe; although minute dark-colored grains, associated with the pyrites, were found to give an intense manganese reaction. From the residue after the action of the nitric acid, a solution of carbonate of soda removed a portion of silica; and the remainder, dried at 300° F., was free from iron and from manganese. Its analysis is given under IX; while that of the matters dissolved by nitric acid and carbonate of soda from 100 parts of the rock, will be found under IX A.

A dyke of trachyte near to the last, and very similar to it in appearance, was submitted to the action of nitric acid, but the insoluble residue was not treated by carbonate of soda. Its analysis is given under X, while that of the soluble matters is to be found under X A. A white trachyte from a dyke at Lachine, resembled the preceding, but was somewhat earthy in its aspect, and effervesced with nitric acid, which removed a portion of lime equal to 7.40 per cent of carbonate. On boiling the pulverized rock with nitrate of ammonia, an amount of lime equal to 5.33 per cent of carbonate was dissolved. An accident prevented the complete determination of the alkalies in the feldspathic residue of this trachyte; and the soluble silica was not removed previous to the analysis, whose result is given under XI. The proportion of the potash to the soda was however found to be, by weight, nearly as two to three. The matters dissolved by nitric acid will be found under XI A.

Another dyke of trachyte from Lachine was concretionary, and stained by infiltration; the interior of the concretions was white and earthy. The substances removed from 100 parts of the rock by nitric acid and carbonate of soda, are given under B. A partial analysis of the insoluble residue showed it to be a feldspar allied to those of the preceding trachytes: the quantities of potash and soda were however nearly in the ratio of four to three.

A large dyke of trachyte in the limestone quarries at the Mile End, near Montreal, is remarkable for the amount of carbonates which it contains. It is grayish-white, with dark grey spots, granular, sub-vitreous in lustre, and holds a few crystals of hornblende.. By ignition it loses 11.0 per cent. of its weight. In powder it effervesces freely with nitric acid, disengaging carbonic acid, and when heat is applied, red fumes from the peroxydation of the iron. 100 parts of the rock yielded in this way the soluble matters given under XII A. The composition of the residue, from which the soluble silica was not removed, is given under XII.

	IX.	X.	XI.	XII.
Silica,...............	63.25	62.90	58.50	61.62
Alumina,............	22.12	23.10	24.90	21.00
Lime................	.56	.45	.45	2.69
Potash,.............	5.92	2.43	....	4.66
Soda................	6.29	8.69	....	5.35
Volatile............	.93	1.40	2.10	2.37
	99.07	98.97		97.69

A second determination of the alkalies in a portion of the trachyte IX, which had not previously been treated by acid, gave potash 5.40 and soda 6.49. A second analysis of X gave potash 2.28, and soda 7·95.

	IX A.	X A.	XI A.	B.	XII A.
Silica, ...	1.43	....	....	5.00	....
Alumina..................	2.43	....	1.27	1.32	4.84
Peroxyd of iron	2.40	2.84	1.47	2.51	2.63
Lime	.60	1.86	4.14	3.50	6.49
Magnesia.................	....	....	1.34	1.35	1.70
Potash, ...	.40	.25	undet.	undet.	undet
Soda.....................	.98	.21	"	"	"
Red oxyd of manganese,....	1.31	.87	....	....	....

Of the matters soluble in nitric acid in the last-described trachyte, XII, the lime in the form of carbonate would equal not less than 11.60 per cent, the magnesia 3.58, and the iron 3.82 per cent of carbonates, in which condition by far the greater part of these bases are probably present.

PHONOLITE.

Associated with the numerous trachytic dykes at Lachine is one of the phonolite already referred to. It is brittle and somewhat schistose, breaking into angular fragments, and appears to consist of a reddish fawn-colored base, in which are disseminated greenish-white rounded masses, often grouped, and apparently concretionary in their structure. These greenish portions are sometimes half an inch or more in diameter, and cover from one third to one half of the surfaces. They are not very distinctly seen unless the rock is moistened. The hardness of the different portions does not greatly vary, and is nearly that of apatite. The specific gravity is very low, being only 2·414. The mass contains small cavities filled with carbonate of lime, which is rarely stained purple: it is also found in small films in the joints. The rock is granular in its fracture, without lustre, and is feebly translucent at the edges. When pulverized, and treated with nitric acid of specific gravity 1.25, a slight effervescence ensues, with abundant red fumes. The mass grows warm, and gelatinizes; and on washing out the acid solution, and treating the insoluble portion with a solution of caustic soda, a white granular residue remains. These reactions are obtained both with the fawn-colored and the greenish portions, but the amount of insoluble matter is greater from the last. The rock is but slightly hygroscopic: a portion of it in powder lost only 0.2 per cent by a prolonged exposure to 212° F., but 7.10 per cent at a red heat.

For the quantitative analysis, the method already indicated was followed. It was found that while a dilute solution of caustic soda removed all of the gelatinous silica separated by the acid, it took up only a trace of alumina; leaving a feldspathic residue which was no longer attacked by nitric acid. The silica was separated from the alkaline liquid, and the acid solution was found to contain, besides alumina and soda, a little potash, some lime, magnesia, and iron, and traces of manganese. The greater part of the lime is evidently present as carbonate; for when a portion of the pulverized phonolite, which gave to nitric acid lime equal to 4.36 per cent of carbonate, was boiled with a solution of nitrate of ammonia, there were dissolved 3.87 per cent of carbonate of lime; besides which there was a separation of a considerable amount of oxyd from the decomposed carbonate of iron. From this reaction, and from the entire absence of sulphur, which was carefully sought for, it is probable that the whole of the iron, except the small portion of peroxyd which colors the rock, exists in the state of carbonate. In the following analyses, therefore, the lime and the iron, as well as a little magnesia, are calculated as carbonates. XIII is the result obtained with four grams of the reddish portion of the phonolite, as free as possible from the green; and XIV was obtained with two and a half grams of a mixture of the two colors.

	XIII.	XIV.
Soluble silicate, zeolite (A), by difference.	46.57	36.16
Insoluble silicate, feldspar (B)	45.75	55.40
Carbonate of lime	3.63	4.36
" iron	3.52	3.72
" magnesia	.53	.36
	100.00	100.00

In order to fix the composition of the soluble silicate, the amounts of the insoluble residue and of the separated silica, alumina, and alkalies, having been carefully determined, and the lime, magnesia, and oxyd of iron calculated as carbonates, the water was estimated by the loss. In this way were obtained the results given under XIII A, and XIV A; while the analyses of the insoluble silicate, which is a potash feldspar, are given under XIII B, and XIV B.

	XIII A.	XIV A.	Natrolite.	Analcime.
Silica	51.96	51.66	47.40	54.06
Alumina	24.42	24.38	26.09	23.20
Soda	12.93	13.05	16.02	14.10
Potash	1.15	1.28	....	....
Water	9.54	9.13	9.05	8.10
	100.00	100.00	100.00	100.00

The composition of this zeolitic mineral is intermediate between analcime and natrolite; but the readiness with which it gelatinizes with acids, leads to the conclusion that it belongs, in great part at least, to natrolite. The theoretical composition of these two zeolites is for the sake of comparison, placed alongside of the two analyses of the soluble portion of the phonolite.

	XIII B.	XIV B.
Silica	59.70	60.90
Alumina	23.25	24.45
Lime	.99	.45
Potash	9.16	undet.
Soda	2.97	"
Volatile	2.23	2.10
	98.30	....

The feldspars of the above trachytes and phonolite offer some considerable variations in their composition, especially in the proportions of the alkalies. In IX the proportions of potash and soda are nearly the same as in the trachytes of Brome, Shefford, and Chambly; and the same is true of XII. These are doubtless to be regarded as varieties of orthoclase with a large amount of soda, while in the feldspar from the phonolite the proportion of soda is very small. In X, on the contrary, the large predominance of soda indicates a composition approaching that of albite. It is further apparent, from a comparison of the feldspars of the other trachytes whose complete analyses are not given, that the proportions of the alkalies are liable to considerable variation, even in adjacent and apparently similar dykes. All of the above feldspars are probably to be referred to orthoclase, or to albite; but these, in the earthy trachytes, have undergone a commencement of decomposition; which consists in the loss of a portion of silica and alkali, and the combination of water, resulting in a formation of kaolin. An admixture of this substance will explain the increased amount of alumina, the deficiency of silica, and the presence of water in the feldspars of the more earthy of these trachytes.

These trachytic dykes are not confined to the vicinity of Montreal. To the southward, on the shores of Lake Champlain, there is found in and about Burlington, Vermont, a vast number of dykes of intrusive rock; some of which appear to intersect the strata of the Quebec group, and others those of the Trenton group. Some of these are described as being of greenstone; and others, as a white or yellowish-white feldspathic rock, often porphyritic from the presence of feldspar crystals. The base of a yellowish-gray porphyritic dyke from Shelburne, having a rough fracture, and a specific gravity of 2.60, gave to Prof. G. F. Barker, silica 67.30, alumina and peroxyd of iron 19.10, lime 0.79, magnesia, traces, potash 4.74, soda 6·04, volatile 1.70, = 99.67. It contained a little intermingled quartz; and the mass resulting from the fusion of the rock with an alkaline carbonate, afforded traces of a sulphuret. (Geology of Vermont, pages 579–707.)

Somewhat to the south of Burlington, on the west side of Lake Champlain, and near to Essex, there is a great mass of intrusive rock, found in the slates of the Hudson River formation. As described by Emmons, it is interstratified in an irregular manner among the layers of the unaltered sedimentary rocks, and has a fissile and schistose structure, which gives, at first sight, the aspect of stratification to what is undoubtedly an intrusive rock. When exposed to the action of the waves on the lake-shore, its structure appears to be columnar, and sometimes concretionary. This rock is described as composed of a reddish or pale leek-green compact feldspar, holding crystals of the same mineral. (Geology of New York, vol ii, page 84.) These intrusive feldspathic rocks on Lake Champlain resemble closely the trachytes of Montreal and Chambly,—with the latter of which, the trachyte of Shelburne, the only one of them which has been chemically examined, closely agrees in composition.

Dolerites.

The anorthosites, which yet remain to be described, may be divided into two groups,—those composed of anorthic feldspars with augite, constituting the dolerites, and those in which similar feldspars are associated with hornblende. The general geognostical relations of these two groups of rocks in the districts under discussion have already been indicated.

Grenville.—It has already been stated on page 163 that the oldest known intrusive masses which traverse the Laurentian series are of dolerite, and that the dykes of this rocks are intersected by the syenite, which was succeeded by the orthophyre or quartziferous porphyry, Nothing corresponding to the syenite or the orthophyre is met with among the adjacent Lower Silurian strata, which are seen to repose upon the worn surfaces of these intrusive rocks. A fourth series of dykes of a porphyritic dolerite is however found to cut all of the preceding rocks, and is perhaps identical with some of the dolerites which intersect the Silurian rocks of the island of Montreal. In the other parts of the Laurentian series, so far as yet examined, intrusive rocks have been but seldom met with. Much of what has been called syenite and granite in various parts of the Laurentian region, seems, like the hypersthenite and other anorthosites of the Labrador series, to be indigenous.

The dykes of this most ancient dolerite or greenstone in Grenville, have a well-marked columnar structure at right angles to the plane of the dyke. They are fine grained, dark greenish-gray in color, and weather greyish-white. Under a lens, the rock is seen to consist of a greenish-white feldspar with a scaly fracture, mingled with grains of pyroxene, occasional plates of mica, and grains of pyrites. It contains no carbonates. Two analyses of portions of the dolerite, from dykes differing a little in texture, gave as follows under XV and XVI:

	XV.	XVI.	XVII.
Silica	50.35	50.25	52.20
Alumina	17.35	32.10	18.50
Peroxyd of iron	12.50		*10.00
Lime	10.19	9.63	7.34
Magnesia	4.93	5.04	4.17
Potash	.69	.58	2.14
Soda	2.28	2.12	2.41
Volatile	.75	1.00	2.50
	99.04	100.72	99.26

The iron in these analyses, although given above as peroxyd, exists in the form of protoxyd, and in the second specimen, in part as a sulphuret. These rocks, which appear to have the composition of mixtures of a basic feldspar with pyroxene, do not differ from ordinary dolerite.

The newer dolerite, which cuts the three other classes of eruptive rocks in the Laurentian region, has a grayish-black, very fine-grained base, earthy and sub-conchoidal in fracture, and resembling somewhat the preceding. It contains small brilliant black grains of ilmenite, with others of sphene, and small scales of mica. Occasional masses of black cleavable augite, sometimes half an inch in diameter, give to the rock a porphyritic character. It contains besides, small cleavable masses of white carbonate of lime, with which the whole rock seems penetrated, When in powder, it effervesces freely in the cold with dilute nitric acid, and the solution evolves red fumes on heating. In this way there were dissolved, lime, equal to 8.70 per cent of carbonate, 0.50 of magnesia, and 6.50 of alumina and oxyd of iron = 15.70 per cent. The residue dried at 211° F, equalled 83.80 per cent. A portion of aluminous silicate had evidently been attacked by the acid. The dried residue gave on analysis the results which will be found above under XVII.

The dolerites of the Montreal district, besides forming numerous dykes, constitute the chief portions of the mountains of Mon-

* With some titanic acid.

tarville, Rougemont, and Mount Royal. In all of these however great diversities of composition are met with, which will be successively noticed.

MONTARVILLE.—The greater part of Montarville is composed of a coarse-grained granitoid dolerite, in which black cleavable augite predominates,—sometimes almost to the exclusion of any other mineral. Small portions of white feldspar, and scales of brown mica, are sparsely scattered through the rock, with grains of carbonate of lime. The removal of these by solution from the weathered surface often gives to it a pitted aspect. In other portions, the feldspathic element predominates, and the rock becomes porphyritic from the presence of large crystals of augite. The worn surfaces of the dolerite sometimes show alternations of this variety with another which is finer-grained and whiter. The two are arranged in bands, whose varying thickness and curving lines suggest the notion that they have been produced by the flow and the partial commingling of two semi-fluid masses.

Another and remarkable variety of dolerite, found at Montarville, appears to be confined to a hill on the shore of the little lake about half a mile northward from the manor-house. The whole of this hill, with the exception of some adherent portions of indurated shale, seems to be composed of a granitoid dolerite, containing a large proportion of olivine. This mineral occurs in rounded crystalline masses or imperfect crystals from one tenth to one half an inch in diameter, associated with a white or greenish-white crystalline feldspar, black augite, a little brown mica, and magnetite.

The proportion of olivine is very variable, but in some parts it is the predominant mineral. Its color is olive-green, passing into amber-yellow. The grains, which are translucent, are much fissured and very brittle. The pulverized olivine gelatinizes with chlorhydric acid in the cold, and is almost instantly decomposed when warmed with sulphuric acid diluted with its volume of water, the silica separating chiefly in a flocculent form, and enclosing small grains of the undecomposed mineral, which are left when the ignited silica is dissolved by a solution of soda. A little silica is however retained in solution, and is precipitated by ammonia with the oxyd of iron. Two analyses of different portions of the olivine made in this way gave, after deducting the undecomposed mineral, the following results:

Silica	37.13	37.17 =	Oxygen	19.82
Magnesia	39.36	39.68 =	"	15.87
Protoxyd of iron	22.57	22.54 =	"	5.10
	99.06	99.39		

The augite of this olivinitic dolerite appears in the form of small crystalline grains, and also in short thick and terminated prisms, which are readily detached from their matrix. They are often an inch in length by half an inch in diameter, and are sometimes partially coated by a film of brown mica. These crystals cleave readily, presenting brilliant surfaces, and are black in color, with an ash-gray streak. Their hardness is 6.0, and their specific gravity 3.34. Analysis gave as follows:

Silica	49.40
Alumina	6.70
Lime	21.88
Magnesia	13.06
Protoxyd of iron	7.83
Soda and traces of potash	.74
Volatile	.50
	100.11

The augite which abounds in the non-olivinitic dolerite that forms the greater part of Montarville, does not appear to differ from that just described.

An average specimen of this olivinitic dolerite, or peridotite, was reduced to powder: it did not effervesce with nitric acid, and when ignited lost only 0.5 per cent. When gently warmed with sulphuric acid, the olivine was readily decomposed, with the separation of flocculent silica; and by the subsequent use of a dilute solution of soda, followed by chlorhydric acid, and a second treatment with the alkaline ley, 55.0 per cent of the whole were dissolved. This portion consisted of silica 37.30, magnesia 33.50, protoxyd of iron 26.20, alumina 3.00 = 100.00: being equal to 18.4 of magnesia for the entire mass. In another experiment, 18.0 per cent were obtained. Taking the mean of the two analyses of olivine above referred to, which gives 39.5 per cent of magnesia, 18.0 parts of this base correspond to 45.5 parts of olivine. The remaining 9.5 parts of dissolved matter represent alumina and silica from the feldspar, and oxyd of iron from the magnetite; both of which were somewhat attacked by the acids. The undissolved portion of the rock equalled 44.7 per cent., and appeared to consist of a feldspar, with pyroxene, some mica, and a little magnetite. Its analysis afforded silica 49.35, alumina 18.92, protoxyd of iron 4.51, lime 18.36, magnesia 6.36, loss (alkalies?) 2.50; = 100.00.

In some portions of the dolerite of Montarville, the feldspar is more abundant, and appears in slender crystals with augite, and with a smaller proportion of olivine than the last. A specimen of this variety, being crushed and washed, gave 3·9 per cent. of magnetite, and 10.0 per cent of a mixture of ilmenite with olivine. The feldspar was obtained nearly pure, in yellowish vitreous grains, having a specific gravity of 2.73—2.74, and nearly the composition of labradorite. The results of its analysis are seen under XVIII.

	XVIII.	XIX.
Silica	53 10	53.60
Alumina	26 80	24.40
Peroxyd of iron	1.35	4.60
Lime	11.48	8.62
Magnesia	.72	.86
Potash	.71	undet.
Soda	4.24	"
Volatile	.60	.80
	99.00	....

The dolerite of Montarville is traversed by veins belonging to several different periods. In one instance, the black and highly augitic mass is cut by a dyke of a fine-grained greyish-white dolerite. This is intersected by a dyke of a fine-grained greenish rock, which, in its turn, is cut off by another small dyke which is grayish-white like the first.

ROUGEMONT.—The rocks of Rougemont offer a general resemblance to those of Montarville. Some portions are a coarse-grained dolerite, in which augite greatly predominates, with grains of feldspar, and a little disseminated carbonate of lime. In some parts, the augite crystals are an inch or more in diameter, with brilliant cleavages; and grains of pyrites are abundant, with calcite in the interstices. This rock resembles the highly augitic dolerite of Montarville. Olivine is very abundant in two varieties of dolerite from Rougemont. One of these has a grayish white finely granular feldspathic base, in which are disseminated black augite and amber-colored olivine, the latter sometimes in distinct crystals. The proportions of these elements sometimes vary in the same specimen; the feldspar forming more than half the mass in one part, while in another the augite and olivine predominate. By the action of the weather, the feldspar acquires an opaque white surface, upon which the black shining augite and the rusty-red decomposing olivine appear in strong contrast.

The dolerite of this mountain is traversed by numerous dykes, some of which are diorites like those of Monnoir and Belœil, about to be described. A dyke of compact dolerite, holding crystals of feldspar and grains of olivine, is found intersecting the strata of the Hudson River formation at St. Hyacinthe.

MOUNT ROYAL.—This hill which rises immediately in the rear of Montreal, consists for the most part of a mass of highly augitic dolerite. In some parts large crystals of augite, like those of Montarville, are disseminated through a fine-grained base, which is dark ash-gray in color, and often effervesces freely with acids, from the presence of a portion of intermingled carbonate of lime. At other times this is wanting, and the rock is a mass of black crystalline augite, constituting a veritable pyroxenite, from which feldspar is absent. Mixtures of augite with feldspar are also met with, constituting a granitoid dolerite, in parts of which the feldspar predominates, giving rise to a light grayish rock. Portions of this are sometimes found limited on either side by bands of nearly pure black pyroxenite, giving at first sight an aspect of stratification. The bands of these two varieties are found curiously contorted and interupted, and as at Montarville, seem to have resulted from movements in a heterogeneous pasty mass, which have effected a partial blending of an augitic magma with another more feldspathic in its nature.

The more augitic parts of Mount Royal contain, like the similar varieties from Rougemont and Montarville, considerable portions of magnetite, and some ilmenite. At the east end of the mountain a variety of dolerite, containing olivine, occurs. It consists of a base of grayish-white granular feldspar, which in the specimen examined constitutes about one half of the mass, and encloses crystals of brilliant black augite, and of semi-transparent amber-yellow olivine. This rock closely resembles the feldspathic peridotite of Rougemont, described above; but the imbedded crystals are somewhat larger, although less than those in the dolerite of Montarville. A portion of the feldspar, freed as much as possible from augite, furnished by analysis the result already given under XIX; which shows that it approaches labradorite in composition.

DIORITES.

YAMASKA.—It now remains to describe the diorites which have already been noticed as forming several important masses among the intrusive rocks of the Montreal group. In the first place may be considered that of Yamaska. The greater part of this mountain consists, as already described, of a micaceous granitoid trachyte; but the southeastern portion is entirely different, being a diorite made up of a pearly white crystalline translucent feldspar, with black brilliant hornblende, ilmenite, and magnetic iron. This rock is sometimes rather fine-grained, though the elements are always very distinct to the naked eye. In other parts are seen large cleavage-surfaces of feldspar half an inch in breadth, which exhibit in a very beautiful manner the striæ characteristic of the polysynthetic macles of the triclinic feldspars. The associated crystals of hornblende are always much smaller and less distinct, forming with grains of feldspar, a base, to which the larger feldspar crystals give a porphyritic aspect. Finer-grained bands, in which magnetite and ilmenite predominate, traverse the coarser portions, often reticulating; and the whole mass is also occasionally cut by dykes of a whitish or brownish-gray trachytic rock, which are often porphyritic, and may perhaps be branches from the trachytic part of the mountain.

A portion of the coarse-grained diorite selected for examination, contained, besides the minerals already enumerated, small portions of blackish mica, with grains of pyrites, and a little disseminated carbonate of lime, which caused the mass to effervesce slightly with nitric acid. The macled feldspar crystals, sometimes half an inch in length, were so much penetrated by hornblende that they were not fit for analysis; but by crushing and washing the rock, a portion of the feldspar was obtained, which did not effervesce with nitric acid, and contained no visible impurity, except a few scales of mica; its specific gravity was 2.756—2.763. It was decomposed by hydrochloric acid, with separation of pulverulent silica; and its analysis, which is given under XX and XXI, shows it to be near to anorthite, and identical in composition with the feldspar of a diorite from Bogoslowsk, in the Ural Mountains. This is associated with a greenish-black hornblende containing some titanic acid, with a little mica, and some quartz. (R. H. Scott, L. E. and D. Philos. Magazine [4], xv, 518.)

MONNOIR.—Monnoir or Mount Johnson is composed of a diorite, which, in its general aspect, greatly resembles that of Yamaska just described, except that it is rather more feldspathic. The finer-grained varieties are grayish in color, and exhibit a mixture of grains and small crystals of feldspar, with hornblende, brown mica, and magnetite. Frequently however the rock is much coarser-grained, consisting of feldspar grains, with slender prisms of black hornblende, often half an inch long and tenth of an inch broad, and numerous small crystals of amber-colored sphene. In this aggregate there are imbedded cleavable masses of the feldspar, sometimes an inch long by half an inch in breadth. At the southern foot of the mountain, large blocks of the coarse-grained diorite are found in a state of disintegration, affording detached crystals of feldspar with rounded angles, and weathered externally to an opaque white, from a partial decomposition. Near to the base of the mountain, a coarse-grained variety of the diorite encloses small but distinct crystals of brown mica; and a fine-grained micaceous variety, containing sphene, occurs near the summit.

The feldspar, in all the specimens examined from this mountain, appears to be uniform in character. Its color is white, rarely greenish or grayish; it has a vitreous lustre, inclining to pearly, and it is somewhat translucent. The cleavages of this feldspar resemble those of oligoclase, with which species it also agrees in specific gravity and chemical composition. The macled forms, so common in the crystals of triclinic feldspars, have not however been detected in the specimens from this locality. A fragment of a crystal gave a density of 2.631, and another portion in powder, 2.659. The results of its analysis are given under XXII and XXIII.

	XX.	XXI.	XXII.	XXIII.	XXIV.
Silica	46.90	47.00	62.05	62.10	58.30
Alumina	31.10	32.65	22.60	....	24.72
Peroxyd of iron	1.35		.75	....	
Lime	16.07	15.90	3.96	3.69	5.42
Magnesia	.65	....	....	....	.91
Potash	.58	....	1.80	....	2.74
Soda	1.77	....	7.95	....	6.73
Volatile	1.00	....	.80	....	.50
	99.42	....	99.91	....	99.32

BELŒIL.—The specimens which have been examined from this mountain consist of a kind of micaceous diorite. The feldspar, which so far predominates as to give a light gray color to the mass, is in white translucent vitreous cleavable grains; associated with small distinct prisms of black hornblende, scales of copper-colored mica, and grains of magnetite. The analysis of the feldspar, extracted by washing a portion of the crushed rock, and still containing a little mica, is given above under XXIV. This result approaches to those obtained from the micaceous feldspar rock of Yamaska, V and VI; which has been described as a kind of trachyte, and with the rock of Belœil seems to constitute a passage between the trachytes and diorites.

RIGAUD.—A portion of Rigaud Mountain consists of a rather coarse-grained diorite, which is made up of a crystalline feldspar, white or greenish in color, with small prisms of brilliant black hornblende, and crystals of black mica. In some specimens the feldspar, and in others the hornblende predominates. This rock resembles the diorites of Belœil and Monnoir.

The granitoid dolerites of the Montreal group, containing coarsely crystalline augite and olivine, break through the Lower Silurian strata; and portions of these two minerals, probably derived from these intrusive rocks, are found in the dolomitic conglomerates near Montreal, which in some cases include masses of Upper Silurian limestone, and are cut by dykes of a fine grained dolerite. These, which perhaps correspond to the newer dykes of the same rock at Grenville, show that there were at least three distinct eruptions of dolerite,—one during the Silurian period, one before it, and another after it. The trachytes of Montreal and Chambly appear to be still more recent than these, and to traverse the newest dolerites.

The trachytes of Brome and Shefford seem to constitute a group apart; but the diorites of Yamaska and Mount Johnson, although similar in aspect, differ widely in chemical composition. Facts are still wanting to establish the geological age of these intrusive masses. The different dolerites, which are related in mineral composition, belong as we have seen to different geological periods; and it would not be safe to affirm that the different diorites or the different trachytes of this vicinity are contemporaneous. Nor, on the other hand, should even great discordances in chemical or mineralogical constitution be necessarily regarded as establishing a difference in the age of eruptive rocks. Evidence to the contrary of this is seen in the contiguous and intermingled masses of black pyroxenite and grey feldspathic dolerite in Mount Royal and

Montarville; and it is not improbable that the olivinitic dolerite which is associated with these, may be contemporaneous. If as has been maintained in the first part of this paper, the various intrusive rocks are only dis laced sediments of deeply-buried and probably unconformable strata, it will readily be conceived that plastic masses of very unlike characters may be ejected simultaneously along a line of disruption.

The various intrusive masses of the Montreal group which have been here described, appear, from their compact and crystalline structure, to have been displaced and consolidated under the pressure of a considerable mass of superincumbent strata. The fact that even their summits, which are in some cases more than 1000 feet above the present level of the plain, appear equally solid and crystalline with their bases, implies the removal by denudation, since the eruption of these masses, of a thickness of s diment ry strata much exceeding their present height. This denudation must however have taken place before the eruption of the later trachytes and dolerites; since the dolomitic conglomerates, which enclose the fragments of the olivinitic dolerite and of Lower and Upper Silurian rocks, repose unconformably upon the Laurentian and the various Lower Silurian strata, in such a manner as to show that these offered nearly their present distribution at the epoch of the deposition of the conglomerates. If then, as is probable, the exposure by denudation of the whole of the eight hills which have been described, took place at one e och, these are all shown to have a greater antiquity than the trachytes and the dolerites, which traverse the conglomerates. The fine-grained and earthy trachytes of Montreal are consequently far more recent than the crystalline ones of Brome and Shefford; with which however, some of them agree in chemical composition.

The general absence of granite from among these intrusive masses is a fact worthy of notice. Quartz has not yet been detected in the feldspathic rocks of Brome and Shefford; although, as above mentioned, the base of the feldspathic porphyries of Chambly, and Shelburne, contains a slight excess of silica. The granitic rocks of Shipton, and of St. Joseph on the Chaudière appear to be indig nous masses, belonging to the strata of the Quebec group; but the higher fossiliferous formations to the east of the Notre Dame Mountains, are traversed in various places by veins and great masses of intrusive granite, as in Stanstead, Barford, and many other places to the northeast, and along the frontier of Canada. It is worthy of note, that the intrusive masses on the two sides of the mountain range are, so far as yet observed, entirely distinct in character; and that eruptive rocks are generally wanting among the Notre Dame Mountains, which consist chiefly of stratified rocks. It is also to be remarked, that the intrusive granites at their eastern base, are not unlike, in mineralogical characters, to the indigenous granites of the mountains; thus suggesting the view that these are possibly the source of the intrusive granites which break through the Devonian strata. A similar relation has been pointed out by Durocher, in Scandinavia, where the palæozoic strata are broken by intrusive masses of granite, orthophyre, zircon-syenite, and diorite. These rocks, according to him, are specifically analogous to those of the underlying primitive gniess, but petrographically distinct. (Bull. Soc. Geol. de France, [2], vi 33.) These facts are in accordance with the theory of eruptive rocks developed at the commencement of this paper; and it would be easy to extend the comparison to the intrusive diorites and dolerites about Montreal, and to show their resemblance with the stratified feldspathic rocks of the Labrador series. (Silliman's Journal [2], xxix, 283, and xxxi, 414.)

IV. Local Metamorphism.

In the second part of this paper I have asserted that the silicated minerals of crystalline rocks have a two-fold origin. In the first place they may result from the molecular change of silicated sediments. These are either derived from the mechanical disintegration and partial decomposition of pre-existing silicates, or have been generated by chemical processes in waters at the earth's surface. In this way steatite, serpentine, pyroxene, hornblende, chlorite, and in many cases garnet, epidote, and other silicates, are formed by a crystallization and molecular re-arrangement of chemically formed silicates, in a manner analogous to that in which mechanically derived clays are converted into crystalline species. I have however pointed out that in the second place many of these silicated minerals may be generated by chemical reactions which take place among the mechanically mixed elements of sediments under the influence of heat aided by alkaline solutions. Both of these methods are involved in rock-metamorphism; and in the case of the local alteration of rocks by igneous masses, it is easy by comparative examinations to trace the chemical changes involved in the production of silicated minerals by the second method. In this way Delesse has shown that in several cases where the chalk of Ireland has been altered by the proximity of intrusive traps, the sand and clay which the former contain have been converted into calcareous silicates. (Ann. des Mines [5], xii, pp. 189, 208, 212.)

An instructive example of this process is furnished at Montreal, where the bluish fossiliferous limestone of the Trenton group is traversed by dykes of dolerite, which are subordinate to the great intrusive mass of Mount Royal. The limestone for a distance of a foot or two, is hardened, but retains its bluish tint. Within a few inches, it is changed to a greenish-white color, which is seen to be due to a granular mineral disseminated in the white carbonate of lime. The unaltered limestones from the vicinity contain variable amounts of insoluble argillaceous matters. A specimen treated with dilute hydrochloric acid, left a residue of about twelve per cent of a fine clayey substance, colored by a small amount of carbonaceous matter, and mixed with a little pyrites, which was removed by dilute nitric acid. This residue, after ignition, gave to a solution of carbonate of soda, 9 5 per cent of its weight of soluble silica; and the insoluble portion, being submitted to analysis, gave the result I. A portion of the limestone which was near to the intrusive rock, and had become hardened and partially altered, was subjected to the action of dilute nitric acid, and gave an insoluble residue with the composition II The more thoroughly altered greenish limestone was also treated with dilute nitric acid, which dissolved the carbonate of lime, and left a residue, the analyses of which, from two different portions of the rock, are given under III and IV.

	I.	II.	III.	IV.
Silica,	73.02	54.00	42.60	40 20
Alumina,	18.31	14.00	13 70	9.30
Lime,	.93	16.24	31 69	36.40
Magnesia,	.87	5 27	4 17	3.70
Protoxyd of iron,	traces	3.60	4.68	5.22
Potash,	5.55	8 14	undet.	undet.
Soda,	.89	1.22	"	"
Volatile,	....	.90	1.20	1.20
	99.57	98.77	98.04	95.02

The residue from the unaltered limestone, including the silica soluble in alkalies, contains nearly 75.5 hundredths of silica, and

16 5 of alumina. These, in the vicinity of the dolerite, have become saturated with protoxyd bases, including the small portions of magnesia and of oxyd of iron which the limestone contains. This process evidently involves a decomposition of the carbonate of lime, and the expulsion of the carbonic acid. It is worthy of remark that while the unaltered limestone contains a little carbonate of magnesia, the rock from which III was obtained yielded to dilute nitric acid not a trace of magnesia. II marks an intermediate stage in the process, and shows moreover that the alkalies are still retained in combination with the alumonius silicate. These granular silicates, which have been formed by local metamorphism, might, under favorable circumstances, have crystallized in the forms of feldspar, scapolite, garnet, pyroxene, or some other of the silicious minerals which so often occur in metamorphic limestones. The agent in producing these silicates of protoxyds at the expense of the carbonates of the limestone, was probably a portion of alkaline salt, either derived from the feldspathic matter of the limestone, or possibly infiltrated from the contiguous feldspathic rock; whose elevated temperature produced the reaction which has resulted in thus altering this limestone.

Similar examples of local alteration are met with in several other places near to the intrusive rocks of the Montreal group. The schists of the Utica formation in contact with a dyke of intrusive rock at Point St. Charles, and also near a mass of trachyte on a small island opposite the city of Montreal, occasionally exhibit small crystals of pyroxene, and in some cases prisms of hornblende. Among similarly altered shales at Rougemont are beds which consist of a highly ferriferous crystalline dolomite intermingled with dark-green cleavable hornblende, which forms thin layers, or in other cases encloses small rounded masses of the dolomite. (See for a description and analyses of this rock the Geology of Canada, page 634.)

At Montarville the shales of the Hudson River formation are altered in the vicinity of the dolerite which forms the mass of the mountain. Some portions of the strata are very fine-grained, reddish-brown, and have an earthy sub-conchoidal fracture, with occasional cleavage joints. The hardness of this rock is not great, and it is apparently a kind of argillite; but between two beds of it is one of a harder coarse-grained rock, greenish-gray in color, and mottled with a lighter hue. This appears to be feldspathic in composition, and is penetrated in various directions by numerous slender prisms of black cleavable pyroxene, sometimes half an inch in length. The layers of sedimentation are distinctly marked in this bed, as well as in the finer-grained strata which enclose it; and the whole affords an interesting example of the different effects of the same agency upon beds of unlike composition; although it would be impossible without comparative chemical analyses to determine whether the silicate which has here crystallized in the form of pyroxene existed in the unaltered sediment, or whether, as in the case of the uncrystallized silicate from the altered limestone at Montreal, it has been generated under the influence of the intrusive rock. In by far the greater number of cases, the only apparent effect of the igneous rocks in the region under description upon the palæozoic limestones and shales, has been a very local induration. The appearance of crystals in these circumstances is a comparatively rare occurence, and seems to depend upon conditions which are exceptional, showing, as I have elsewhere remarked, that heat and moisture are not the only condition of metamorphism. (Silliman's Journal [2], xxxvi, 219.)

With these few examples of local metamorphism I conclude the present paper; proposing however to give in a subsequent one the results of some investigations of certain indigenous crystalline rocks.

Montreal, March 15, 1864.

CHEMISTRY OF MANURES.*

CINEREAL† CONSTITUENTS OF PLANTS.—It is not however exclusively by carbon, nitrogen, and the elements of water that

* Continued from page 124.

† This term *cinereal*, from *cineres*, ashes, may prove convenient to indicate, without periphrasis, the ash-constituents of plants in contradistinction from their volatile elements. Some writers fall into the error of employing the epithet "mineral" to denote the ash-ingredients; an error in nomenclature probably arising from some confused impression that, because of its earthy derivation, the ash of plants is more mineral in character than the volatile or gaseous elements which air supplies and fire dissipates. The illustrious author of the min ral-theory seems, in some of his earlier writings, himself to have countenanced this error. Nevertheless, its simple indication suffices for its refutation. Carbon and

plants are nourished; nor is it solely in quest of food, such as the leaves also can assimilate from the air, that the roots spread forth their manifold ramifications amidst the earth.

Liebeg first set forth, in all their peculiar interest and importance, the fixed ingredients of plants; that is the compounds which appear as ash, when the volatilizable air-derived elements of plants are burned off. These ash-ingredients constitute, as he explained, the special (though not the sole) food of the roots; and they are the only kind of nutriment which has its primary and excl.sive source in the soil.

These essential ash-ingredients, so far as we yet know them, are the two fixed alkalies, potash and soda; two earthy bases, lime and magnesia; one heavy metallic base, oxide of iron; three acids, phosphoric, silicic, and sulphuric; and lastly, chlorine, which, though a gas, is always taken up by plants in fixed combinations (as for example in common salt), so as to remain in the ash or incineration.

Small as are the proportions of these fixed ingredients assimilated by plants during their growth, they are yet as necessary to the plant's development as the carbon and water which make up its main bulk. So again, as between the fixed ingredients themselves, although some of them are needed in larger, and some in smaller proportions, each species of plant having in this respect, its special requirements; although, for example, one ingredient may form more than one half the total ash of a given plant, and another less than a tenth part thereof; yet are they all equally essential to its development, which languishes as much for want of the minutest as of the bulkiest cinereal supply, Soils wholly deficient in any one of the ash ingredients of a particular plant, cannot produce that plant, howsoever abundantly every other of its elements, volatile and fixed, may be supplied. Partial deficiency of either of the normal ingredients of plant-food, whether fixed or volatile, involves a proportionately scanty crop; and no heaping of other

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carbonic acid, nitrogen, ammonia, and nitric acid, oxygen, hydrogen, and water, all appertain to the mineral kingdom, in every sense as fully as silica, potash, the phosphates, &c. The epithet "mineral" applies therefore equally to all the elements, both volatile and fixed, of plant-food; it is for the separate designation of the fixed or ash constituents, that the epithet *cinereal* is proposed. In this sense (to test its convenience) it will be employed in the remainder of this section.

manures on the soil can have the slightest effect, so long as the one ingredient, wholly or partly deficient, remains unsupplied.

Nor does the mere presence of the cinereal plant-food in the soil suffice: it must be availably present. That is, besides any portion, however large, of cinereal element, that may be held in mechanical isolation within the substance of the stones or clods, beyond the reach of the roots; or that may be locked up in chemical combination, too refractory for the solvent agencies present to subdue; besides any isolated or locked-up portion which may, in truth, be regarded as absent for all immediate purposes of nutrition; there must be a sufficiency of ash-constituents, held lightly, either by the surface-action of the moist and porous earth, or (according to another view) by the chemical attraction of the aluminous silicates, in such manner as to be, both physically and chemically, accessible to the roots. No doubt the locked-up materials of one season, may, and do become, in due course of tillage and fallowing, the accessible food of the next; and, indeed, it is to such gradually-decomposing reserves that the prolonged fertility of certain soils, worked by tillage and fallowing only, without manure, is due. But for all immediate purposes, a soil is exhausted, when, rich as it may be in the conditions of future fertility, it lacks an adequate present supply of the ash-constituents of plants, in free accessible diffusion.

High Farming: how far justifiable: at what point exhaustive.—And here it becomes opportune to resume the question of high farming, which in a previous page was reserved for subsequent elucidation.

High farming, as already pointed out, is justifiable in so far as it serves to concentrate, within limits adapted to the assimilative powers and circumstances of annual and biennial plants, the food-supplies diffused by nature over a much wider expanse of time and space, to suit vegetation of perennial growth. But it is of the deepest importance to observe, that the more abundant crops, and apparently increased fertility usually induced by high farming, are in too many cases but the premonitory symtoms of an accelerated process of exhaustion. The semblance of prosperous husbandry thus created is as factitious as the spendthrift's ruinous magnificence maintained by squandering his capital; and "high farming," even when coupled with "high manuring," and the keeping of many cattle for their dung, is often, for the unwary husbandman, only a flowery road to destruction.

For it is to be remembered that a soil may, by the excessive use of lime, common salt, nitrates, and other solvent or disintegrant manures, as also by diligent ploughing, scarifying, crushing, and other processes of mechanical comminution, be made to yield its reserves in accessible form, at an unduly accelerated rate. The same result may ensue, if the volatile forms of plant-food, which nature supplies only in moderate annual proportion, be added in pr fusion to the soil, without due care to conjoin therewith proportionate supplies of ash-constituents, or cinereal food.

Rotation of Crops often Exhaustive.—Even the vaunted system of rotation—*i. e.*, the growth of fodder-crops alternately with cereals, these latter receiving as manure the dung of the cattle fed on the former—is but too often so carried on as to be in truth a spoliatory operation; a sort of artifice, serving only to disguise and retard the period of final exhaustion; which so far from averting, it does but make more profound. For the powerful, deeply-penetrating roots of the fodder-crops extract from the subsoil its ash-constituents; which, after passing through the bodies of the cattle, are deposited in their dung on the surface, thence to sink into the upper layers of the soil, and so to find their way to the fibres of the young, slender-rooted cereal plants; in whose grain they are finally exported from the farm.

Lois-Weedon System; its Spoliatory Character.—The so-called Lois-Weedon system of cultivation is open to similar objection. This system, as is well known, consists in the growing, year after year, upon soil which is never manured, of corn-plants thinly sown in rows, separated by wide intervals; the intervals being each year stirred and fallowed, to become the next year's growing spaces; and so on in annual alternation. This system of husbandry, which may be regarded as an extreme exemplification of Jethro Tull's doctrine, is stated to have elicited from the fields in which it is pursued, a series of full grain-crops for many years in succession. This result is in the highest degree probable. And this apparent prosperity may be kept up for a series of years, longer or shorter for each soil, as this may happen to have been originally more or less richly endowed by nature with cinereal plant-food. But the end of this method also is exhaustion, —inevitable foredoomed exhaustion,—exhaustion of which each "prosperous" crop is but an advancing stage, and whose rate the chemist measures, with stern precision, in the annually lessening weight of a little dust in the pan of a balance. Unless the weight of that dust (the available ash-constituents of the soil) remain year after year a constant quantity, the husbandman, howsoever prosperous he may seem to be, pursues a downward road; and he is fatally preparing for himself or his posterity, impoverishment and final ruin.

DISPROPORTIONATE MANURING.—Nay more: the weight of ash in the balance may even be annually increased, by a profuse manuring of the soil, and yet exhaustion and ruin may impend. This will be the result, if one of the fixed aliments—phosphoric acid for example—be added to the soil in superabundance, without proportionate supplies of other cinereal constituents,—say for example, silica or potash. So, again, if manures which, like guano, are at once nitrogenous and phosphatic, but not proportionately rich in all the cinereal elements of plant-food, be employed in excess, the farming will be higher still, the crops more luxuriant, the "prosperity" more brilliant than ever, and the catastrophe proportionately nearer the more disastrous.

The practice of multiplying cattle on a farm, and of fattening them with the oil of purchased oil-cake, in order that the ash of the cake, after passing through their bodies, may become available for the cinereal replenishment of the soil, is another form of high farming, at present very much in fashion. But, broadly viewed, with reference not to individual but to collective interests, this system also will be found to originate in an oversight, and to end in an illusion. The facts overlooked are, that oil-cake purchased, is also, of necessity, oil-cake sold; that all oil-cake is the produce of land; and that, consequently, what one farm gains, another loses, when oil-cake changes hands. The ash of oil-cake, together with the fertility, immediate or prospective, which that ash represents, is a fixed quantity, which commerce may serve to distribute, but cannot possibly increase. The distributive operation may be more or less useful to vary the apportionment of fertility in space and time. But cake-fed cattle are not, as they are frequently supposed to be, a *source* of cinereal manure; and the practice which grows out of this illusory belief is but one more, and not the least dangerous in its tendency, of the fashionable agricultural abuses decorated with the name of high farming.

Should high farming, in either or all of these spurious forms unhappily become prevalent among civilized nations, so as to bring about the exhaustion of extensive tracts of the earth's surface, at about the same period of time,—say, for instance, in the third or fourth generation hence; in such case the demand for cinereal manures, arising simultaneously over whole continents, would necessarily exceed all possible supplies, and incalculable misery, in the form of famine and pestilence, must ensue.

The exhaustion consequent on scanty manuring has been the theme of many exhortations; but the danger of similar evil from injudicious or excessive manuring has not been sufficiently insisted on.

One more example of this danger is all for which space can be afforded here.

The growth of the wheat-plant may be divided, like that of the biennial turnip, into three main periods;—the first, during which the growing power of the plant is chiefly employed in developing its earliest leaves and its root; the second, during which its vital force is directed to increasing its foliage and shooting forth its stalk; the third, during which flowering and fruition take place, and the grain fills with nitrogenous and amylaceous compounds,—the main objects of its culture. Now, injudicious manuring, with excess of nitrogenous compounds and of the special ash-constituents of straw, may cause such a development of stalk and leaf, and so undue a consumption, by these, of food and force required to form the grain, that, when this comes in its turn to the ripening period, the conditions of its evolution fall short, and the result is a crop of magnificent straw, with only half-filled ears.

All these dangers and disasters disappear, all perplexity ceases, and the course of the farmer becomes clear and safe, if he takes for his guidance the natural laws of husbandry,—prominent among which is that which enjoins the scrupulous restitution to the soil of the ash-ingredients removed in the crop.

Social and Political Aspects of the Question.—By ignorance or neglect of these laws, ancient families, possessed of vast estates, have been brought to ruin; distress, the perturber of dynasties, has befallen great nations; and mighty empires have fallen to decay.

It is a remarkable fact, and well worthy of the meditation of statesmen, that the line which indicates, by its rise and fall, the fluctuating price of corn in France, from year to year, during the first half of the present century, rises, at two points of time, to sudden and conspicuous eminence. Those significant pinnacles bear date 1829 and 1847. The political catastrophes which followed these two seasons of distress respectively, do not require indication. How far the precursory distress depended on inclement seasons, how far on erroneous husbandry, the reporter is not aware. But he believes that no institutions strike root deeply in a country that is badly farmed.

EMPIRICAL MANURES.—From these cursory remarks it will be apparent that manures can only be used with success, when they are applied with judgment and moderation, and with due reference, as well to the nature and condition of the soil to be amended, as to the particular description of the crop to be raised. Empirical mixtures, vaunted as suiting special crops, are likely (even when honestly composed) as often to fail as to succeed, because they are commonly employed, in blind confidence, on all kinds and conditions of soils. So extensively does haphazard prevail, as yet, in this matter, that costly ammoniacal salts or composts are often applied, without avail, to fields which a cheap dressing (say with lime or silica) would have fitted to bear a good crop. Nay, in some cases a manure may chance to be efficient by the very ingredient employed for its adulteration; as, for instance, sand-mixed guano by its silica.

LIEBIG'S MANURES.—The history of Liebig's mineral manure —a mixture of ash-ingredients patented by the illustrious philosopher in April 1845,* as the practical embodiment of his theory published five years previously—is too remarkable to be passed in silence here. This manure is stated in the specification of the patent, to be composed of substances "containing the elements of the ashes of the plants to be grown," ground up, and "occasionally mixed with gypsum, calcined bones, silicate of potash, magnesian and ammoniacal phosphates, and common salt." Here appeared, indeed, to be the elements of a restorative, well adapted to renew, in conformity with theory, the fertility of ash-exhausted soils. Nevertheless this manure, which excited the highest anticipations, and was eagerly tried on fields innumerable, occasioned universal disappointment; and was everywhere abandoned as a failure.

* This patent (No. 10,616, April 15, 1845) is granted to J. Muspratt, as "for a communication from Justus Liebig."

Many, indeed, in the excess of their disappointment, were led to repudiate the "mineral theory" itself, and to impugn all scientific husbandry as a dangerous delusion.

It is now easy, and also in the highest degree instructive, to trace this error of the illustrious philosopher to its source in the then state of science. The special discovery, which has rendered impossible the recurrence of such an error, may also now be pointed out; and this is, in itself, of so much interest and importance that it deserves our most careful attention.

Early View of the Ingestion of Cinereal Aliment.—At the date of Liebig's patent it was universally believed that the ash-constituents of plants were supplied to the roots in moving aqueous solution; *i. e.*, in solutions permeating the soil unchanged, and meeting in its passage rootlet after rootlet, so that the tender spongioles, being immersed therein, could drink. According to this view, it was not the roots which travelled to the ash-constituents, but the ash-constituents which were carried, in solution, to the roots. This belief led Liebig to fear that the more soluble alkaline ingredients of his manure would, by the rain falling on the land, be washed away from the other ingredients, and thus separated therefrom. He therefore directed his mixture to be treated "in such a manner that the character of the alkaline matters may be changed, and the same rendered less soluble"; and he indicated, as the best mode of effecting this object, *the fusion of the materials in a reverberatory furnace.* The danger feared by Liebig was, we now know, illusory; and the treatment he adopted to avert the supposed evil was such as to render his mixture comparatively inert. It was reserved for an English chemist, John Thomas Way, to make, some five years later, the important investigation which led to the abandonment of the above-stated opinion as to the conveyance of liquid plant-food to the roots, and introduced in its stead an entirely new view of the distributive mechanism of the soil.

Absorptive Power of Soils.—Way's observation, briefly stated, was that soils possess an absorptive power, in virtue of which they withdraw from aqueous solutions of saline plant-food filtered through them, sometimes the whole, sometimes the base only, of the dissolved salt. He found that, in the latter case, the acid of the salt from which the soil had thus withdrawn the base, passed through the soil in combination with lime. By a welldevised and extensively-varied series of experiments, he determined the comparative amount of this absorptive power possessed by several varieties of soil, whether natural, or artificially composed. These he tried, both in their raw state, and burned, as also under ordinary and extraordinary conditions of compression, comminution, &c., testing each with solutions of the alkalies and alkaline earths, sometimes caustic, sometimes carbonated, sometimes in combination with the strong mineral acids. By these experiments he confirmed and extended partial observations of like kind recorded long ago by Lord Bacon and Dr. Hales, as also a number of analogous facts, experimentally ascertained by Berzelius and Matteucci abroad, and by Mr Huxtable and Mr. H. S. Thompson in this country. Referring the reader for details to Way's * original papers on the subject, the reporter may simply state here that Way attributes this power to the peculiar properties of the aluminiferous double silicates, which he states to be more abundant in soils in proportion as these possess higher absorptive power. This interpretation of the observed phenomanon has not met with universal acceptance; many, with Liebig at their head, denying the proportionality alleged by Way, and seeing in the absorptive power of soils for salts dissolved in water, only another aspect of the physico-chemical surface-action due to their porosity, and enabling them to absorb gases and vapors from their diffusion or solution in the atmosphere. The reporter, for his own part, rather inclines to the latter view.

But the facts investigated by Way, independently of their physical conditions and theoretical interpretation, possess an importance and a generality which entitle them to rank among the most conspicuous contributions to modern agricultural science. They prove, among other things, that the plant-food arrested by the soil can be delivered only to the spongioles in immediate contact therewith: and that, consequently, these can obtain fresh food only under one of two conditions;—(*a*) when, by the growing of the rootlets, they are pushed forward into contact with fresh portions of the mould; (*b*) when the descent of rain through the soil effects the solution of fresh saline matter, and calls again into play the surface-attraction of the pores, so as to replenish those previously exhausted by the contiguous spongioles. Showers

* Royal Agric. Soc. Journ. 1850-52-55.

therefore are, in a double sense, "genial"; firstly, as liberating within the soil a fresh supply of surface-held plant-food, available for the rootlets to touch and take; secondly, as promoting the growth of the rootlets, and so moving forward thousands of spongioles simultaneously into contact with fresh food-holding surfaces.

These beautiful relations of the soil, the food, and the roots, now that they are discovered, are perceived to be so indispensable, that one almost wonders they were not arrived at by *à priori* reasoning. For, had soils been undefended by this absorptive property, the rainfall of centuries passing through them must have, ages ago, washed away every trace of their soluble salts. Subsoil drainage, so far from tending, as it does, to fertilize land, would but have exposed its sandy remnants to a lixiviating process more rapid and exhausting than even that of the natural filtration.

Distributive Mechanism of Soils.—It does not of course fall within the scope of the present rapid sketch, to trace this newly-discovered property of soils, to all its important consequences. As one example, perhaps the most striking, of these, the reporter would single out the admirable distributive influence of the absorptive power; which (counteracting in this respect the force of gravitation) tends to maintain the nutritive ingredients where they are most needed, *i. e.*, in the upper layers of the soil, leaving the surplus only to be deposited, as in a reservoir, in the layers beneath. Each layer, in fact, when saturated itself, lets pass unchanged the surplus solution, to saturate the layer next below; and so on, in progression, through the whole depth of the cultivable soil.

Reverting, with this property of soils before us, to Liebig's patented manure, we see clearly the cause of its failure. In aiming at its improvement by the reduction of its solubility, the illustrious inventor inadvertently placed himself in opposition to a law of nature. How nobly he retrieved this error will presently appear.

Distributive Mechanism of Farm-yard Dung.—Meanwhile, it is a point worth notice, that an error, similar to Liebig's, is apt to vitiate experimental comparisons between the immediate fertilizing effect of farm yard dung, and that of the ash obtained by its incineration. The inferiority of the ash to the dung itself, as an immediate fertilizer, is commonly ascribed solely to the dissipation by fire of the volatile constituents of dung, and particularly of its ammonia; and much prominence has been given to the results of such trials, as evidence of the alleged inefficacy of cinereal supplies to corn. Among the objections to this line of argument it may be mentioned that the observed difference probably depends, in a considerable degree, on the modification by fire of the ash-constituents themselves. In the unburnt dung, composed, to a large extent, of decaying straw, the cinereal elements are diffused throughout the organic tissues, in a state of infinitesimal molecular subdivision. By the decay of the dung in the soil, the organic molecules are gradually converted into carbonic acid and water, the proper solvents of cinereal food. Thus considered, a decaying straw containing (say) five per cent. of ash-ingredients, constitutes as perfect a piece of distributive mechanism as can easily be conceived, for spreading throughout the soil the needful cinereal restoratives, along with the liquid and the gas requisite for their solution and final delivery to the roots. But this is not all. The straw acts with equal efficacy as a distributive vehicle of the urine with which it is soaked, and of the cinereal and volatile plant-food dissolved therein. Before decay, its fibrous tissues constitute a sponge, to absorb and retain, as also widely to expand, the nutrient solution; and when the sponge has brought this solution into contiguity with an extensive surface of soil it silently disappears; its solid tissues dissolve,—their capillarity, having done its office, ceases to exist,—the capillarity of the soil comes into play, and its pores delicately take up the ailment which he straw, in the act of its dissolution, as delicately deposited. Hoffmann, in one of his *Phantasiestucke*, describes a mysterious hand, which, moving in palpable substance through the air, carries a cup of food to one of the personages of his tale, and having set it down before him, vanishes into thin air. Each fragment of straw in dung acts as such a hand to the soil. The substantive, palpable vehicle melts into gas and water when its work is done. Nor is the space left empty by its disappearance without a special use: it forms a channel for the tender rootlet to travel along,—a channel which the decay of the straw at once hollows out, and warms, and lines with aliment; with aliment, as we have seen, finely divided, surface-held, and provided with its appropriate solvent.

All this delicate adjustment of means to a special end is utterly destroyed by fire, which dissipates the hydro-carbonaceous matter of straw, so that its ash-ingredients, no longer separated by intervening molecules, collapse into dust. In this form they do not occupy a hundredth part of the volume through which they were previously spread; and they are, moreover, very apt to be further compacted by actual fusion during the agitation. Farm-dung ash is particularly liable to vitrification, because its straw contains both the alkaline and silicious elements of glass. The vitreous or semi-vitreous ash thus produced by incineration is but slightly soluble. In a word, the effect of incineration on farm-dung closely resembles that produced by Liebig's furnace-treatment on his Mineral Manure.

These considerations should be attentively borne in mind, in estimating the value of experiments adduced to prove the inefficacy of the *cinereal* constituents of farm-dung, as contradistinguished from its *ammoniacal* ingredients.*

THE NITROGEN THEORY, AND THE DOCTRINE OF SPECIFIC MANURES.—It is not however to be inferred from the foregoing remarks that cinereal plant-food, such as Liebig's manure (or as the ash of incinerated dung), even if supplied in a perfectly soluble form, would be indiscriminately applicable to increase in an equal degree the immediate productive power of all conditions of soil, for every kind of crop. It was against this undue pretension, which was supposed to follow from some of the statements put forth in Liebig's earlier works, that the advocates of the so-called "Nitrogen theory" (who also support the doctrine of "Specific manures") originally raised their flag. It may be doubted whether the illustrious author of the mineral theory, even in his earliest

* In pointing out the valuable distributive properties of farm-dung the reporter would not be supposed to overlook the still wider diffusion of fertilizing matters obtainable by liquid manuring. This system, indeed, has been already indicated as the principal distributive mechanism of the future. It enables the farmer to direct, from a central point radiating streams of plant-food to his remotest fields; and by the mere turning of a tap, to adopt the supply with the utmost nicety to the requirements of every plot. The cartage-cost, and manual labor incurred in spreading dung upon the soil, may thus to a great extent be replaced by steam-power; or even, in favorable cases, by the still cheaper force of gravitation. To soils requiring a carbonaceous supply such as the cattle-litter in dung affords, this material (cut up) might perhaps be economically conveyed in suspension in the liquid manure-streams. For clay, and other insoluble matters capable of suspension in water, this mode of distribution has been found available.

and crudest enunciations of that doctrine, ever committed himself to the fallacy imputed to him by the upholders of the rival system. If he did, he has long since abjured his error; or rather it has fallen, like a deciduous leaf, in the gradual ripening of his opinions during more than twenty years of experiment and research. The reporter believes that, upon this point, there exists at the present time but little real difference between the views of the contending parties; *i. e.*, between those who affirm that the ashes removed in the crop do, and those who maintain that they do not, represent the return to be made to the soil, to keep up its fertility. No two opinions, certainly, can seem more diametrically opposed than these; and at the outset of the controversy, the opposition was not only apparent but real. But for many years past, the disputants have been gradually approaching each other, by approaching the great central truths which lay between them. By the dropping, on both sides, of some earlier crudities, often perhaps rather of phrase than thought, and by the discussion, by common consent, of *matured* opinions only, many of these truths will, the reporter is convinced, be found expressible in terms acceptable to both.

With reference, for example, to the effect of cinereal manuring, both parties will certainly admit that, whether soils be rich or poor, they derive (*cœteris paribus*) from equal increments of their cinereal stock, equal absolute benefit; to be manifested, sooner or later. in equally increased production. It will also be allowed on all hands that soils, already containing enough cinereal food, in the surface-held soluble state, to supply a series of maximum crops, cannot immediately make manifest, and return, in the form of augmented produce, the value of the additional supply received. Such immediate return, it will be agreed, is to be looked for only from soils already exhausted of one or more of their cinereal ingredients; or if not absolutely exhausted thereof, at least deficient of the requisite supplies in the unlocked soluble condition, which alone renders them available for immediate assimilation by plants. Even in this case, moreover, both parties will admit that assimilation cannot take place, and there can consequently be no immediate return, except in so far as all the other conditions (ponderable and imponderable) of plant-growth are simultaneously supplied,—nitrogen among the rest. In mentioning nitrogen, we touch the very centre and throbbing heart of controversy; one party looking to Nature, the other to Art, for sufficient agricultural supplies of this element, in the form of ammonia. Yet both sides must and do admit that each acre of soil receives from nature an annual quantity of ammonia, greater or less as the seasons are more or less propitious; part being supplied by the air, in the manner already explained, part (as we may now fairly presume) being generated within the soil itself, by some reaction analogous to that observed by Schönbein.

Thus much agreed on, both parties would probably be prepared to admit, as a perfect or typical soil, for the growth of any given rotation of maximum crops, one containing a duly proportioned and available supply of all the cinereals requisite during such rotation; and on the other hand, receiving from nature, during the same period, a quantity of volatile plant-food, nitrogenous, carbonaceous, and aquatic, precisely corresponding to this cinereal supply. Assuming, of course, the mechanical and physical conditions of such a soil to be also typically perfect; and assuming it, further, to be worked during a series of typical seasons; it would evidently require only typical manuring; *i e.*, the exact restitution, during each rotation, of the *cinereals* withdrawn by the crops. This is a proposition to which no one, at the present time, will demur. But in reality, as we all know, these various classes of typical conditions, mechanical, physical, chemical, and climatic, are never simultaneously fulfilled. Each deviation from one or more of them involves a corresponding deviation from typical manuring. Hence arises a series of special agricultural cases, as manifold as the changes on a set of bells; and an accurate knowledge of every condition, in each of any number of cases selected for comparison, is necessary for their correct interpretation. It is in the midst of these complications that oversights take place, and differences creep in. Many of these are wholly irrespective of the nature of the soil. Take for example, two experiments, otherwise (by hypothesis) equal, but made in two different counties or districts, *one happening to enjoy, during the growth of the crop,* a larger number of hours of unintercepted sunshine than the other; it is obvious that, notwithstanding the assumed equality on all other points, the results must differ more or less, and may differ very notably, in the two cases. Again, assume, for argument's sake, absolute equality in all the external conditions of plant growth, but a difference in the quality of the seed employed in two trials;

evidently there will be a disparity in the results, which will appear inexplicable, or which will perhaps be attributed, by the advocates of rival theories, to this or that property of the manure employed.

But it is not necessary to go beyond the soil itself in search of such declensions from type. Defects of the soil occur, grade below grade, through all the possible varieties of poverty, down to absolute barrenness; and the characters and causes of defective fertility differ fully as much as do its innumerable degrees. One soil, for instance, will contain but a poor supply of one or more of the essential cinereal ingredients of the plants to be grown, or will even be totally deficient thereof. Another, well endowed with cinereals, duly apportioned to supply the desired rotation of crops, will be deficient of carboniferous material, or non-retentive of moisture, or not porous enough to hold a sufficient supply of air. A third, perfect perhaps in those respects, will fall short as to the peculiar physico-chemical properties necessary for the absorption, or generation, or retention therein, of ammoniacal supplies, in proper proportion to the air and water, to the carbon, and to the cinereals. All parties must assuredly admit, with respect to such soils, that their natural deficiencies, whether cinereal or ammoniacal, aerial, hygroscopic, or carbonaceous, may with propriety be artificially made good,—so far as such amendment be economically possible; and, in each such case, some particular kind of manure will of course prove specially beneficial for the growth of crops. Thus much will be conceded by those who, with Baron Liebig, most strenuously oppose the doctrine of "specific" manures. In some cases, for example, nitrogen will be "specific" for corn; though only in the same sense, and in the same degree, that lime will, in other cases, "specifically" benefit the same crop.

Again, that leguminous crops rapidly assimilate atmospheric ammonia by means of their widely-spread leafage, whereas the cereals, with their scanty foliage, are much more dependent on their roots for ammoniacal supplies,—these are facts which no one will dispute. The use of fodder-crops and cattle-feeding, as means of artificially accumulating the ammonia-supplies naturally diffused over the whole period of rotation, and bringing this concentrated provision to bear on the cereals, which could not else absorb ammonia at a sufficiently rapid rate to keep their nitrogenous on a par with their cinereal, carbonaceous, and aquatic alimentation,—this also will certainly be admitted by all.

This accumulative and distributive agency of a normal rotation of crops, growing (by hypothesis) on a typical soil, most strikingly reflects, in what may be termed the physiological mechanism of agriculture, the regulative influence exercised in mechanics by the fly-wheel; which, in like manner, during each rotation, stores up the momentum gained at the period of maximum impulsion, to give it out as work at the period of maximum resistance. Thus much being admitted by all with reference to the supposed typical soil, there will only remain for consideration the case of soils falling so far short of this hypothetical perfection, with respect to their natural ammoniferous endowments, that the total supply, including that collected by the leguminosæ, proves inadequate to meet the demand of the cereals. The utility, in such cases, of nitrogenous manures, and the propriety of the husbandman's intervention, thus artificially to make good the defect of the natural ammonia-supply, will not by any one be contested.

Thus, point by point, the main ground of difference (the alleged preponderating value of nitrogen) seems reducible to a mere statistical question;—how many European corn-fields are relatively poor in this or that cinereal? how many are deficient of humus, or water, or air? how many fall short as to their natural ammoniferous properties? Whichever element, fixed or volatile, might be indicated by the result of this inquiry, as deficient in the largest number of cases, might be described as the element of *preponderating*" importance, without violence to the opinions of either party.

This method of settling the great nitrogen-controversy would, however, still leave open for discussion a grave question concerning this element of plant-food,—a question which the intellectual forces, heretofore expended in conflict, might be usefully combined to set at rest. This question is, how much ammonia is it possible, in the present state of our industrial resources, to provide for soils not naturally well supplied therewith? If high farming is to become universal, and to be carried out on second and third class soils, at as high a pitch above their natural ammoniferous endowments, as is now aimed at in many English farms, the demand for ammonia seems likely to exceed all the means at our disposal for its supply.

The saving of urban ejecta, and the consequent return to the soil of the enormous masses of cinereals now wasted, appears likely to increase the relative demand for ammonia; especially as poor lands, of naturally low ammoniferous endowments, will probably be those selected (so far as local circumstances permit) for irrigation with town sewage. For, though sewage is rich, as well in the nitrogenous as in the cinereal constituents of the food consumed in towns, it is not proportionately so rich in the former as in the latter ingredients; the reason being that part of the ammonia of food is dissipated during the processes of animal life,* wherea all the fixed cinereal constituents that are taken into the system of adults reappear undiminished in their ejecta. Moreover, no waste necessarily attends the transit of the cinereals in solution, along the subterranean conduits, from the houses in which they are produced to the fields in which they are consumed; whereas the ammonia of sewage is liable to undergo a considerable amount of waste during its passage from town to country in the ordinary conduits; a circumstance which (it may be parenthetically mentioned has led Mr. F. O. Ward to the belief that, in the future progress of urban organization, it will be found economical to provide separate urinary and fæcal systems; bringing thus, by a further refinement, the collective organism into closer correspondence with the individual. The probability of this ulterior improvement will, perhaps, be the more readily recognized, when it is considered that three fourths and upwards of the value of human ej cta are comprised in the urine,—only the fractional remainder in the fæces. But, as even the separation of sewage from rainfall is not yet officially admitted, it would be a premature and therefore a hopeless crusade to press, at present, for further niceties of organization. These will come in due time, when the residua of towns, now officialy described as "a nuisance to be got rid of," shall be regarded in their just light as "a property to be administered," —nay more, as the property on whose sound administration depends, in a greater degree than on any other single condition, the lasting prosperity of nations.

Reverting to the nitrogen question, should it prove true that a dissipation of ammonia takes place, as some experimentalists maintain, during the growth of cereal plants; and should this waste

* This point has been made the subject of direct experiments by Boussingault, Barral, Regnault, Reiset, and Lawes, and it may be taken as a fair average estimate, that, of the nitrogen consumed in the food, only about four fifths are recoverable in the ejecta.

be found to exceed the ammonia-accumulating power of the leguminosæ, when grown, in due proportion, in rotation with cereals; under such hypothetical conditions the drain of ammonia will doubtless, in a still larger number of cases, exceed the natural supply, and compel recourse to ammoniacal manures.

Liebig's view of the sufficiency of natural ammonia-supplies, even for the purposes of high farming, when fairly and skilfully conducted on suitable soils, is not incompatible with the opinion that artificial ammonia-supplies may become in an increasing degree the husbandman's principal requirement hereafter, under the modified agricultural conditions rapidly sketched above.

How far it may be wise to encourage the development of such a system, is a serious question. For, unless some cheap source of ammonia should be in the meantime discovered, the exhaustion of the guano-deposits (relatively a limited quantity) must, under such circumstances, bring ruinous disaster in its train. The collapse of the foundation would of necessity involve that of the edifice reared thereon; and large populations, called into existence by these factitious means, would find themselves deprived, more or less suddenly, of their accustomed food-supplies.

Considered from this point of view, the great "nitrogen question" merits the gravest consideration, not only of agriculturists, but also of statists and politicians.

Thus far the matters in dispute seem capable of settlement in terms admissible by both the contending parties, but the questions at issue comprise points, or rather perhaps are presented in forms, on which the divergences of opinion appear too wide to afford any prospect of harmonization.

Thus, for example, it is affirmed on one side, and denied, point blank, on the other, that potash acts "specifically" (*i. e.*, otherwise than in conformity with Liebig's law) in promoting the growth of the leguminous plants, such as beans and peas. Those who maintain this view allege, as their reason, that the leguminosæ, though characteristically rich in nitrogen, require potassic, not ammoniacal manures. The fallacy of this reasoning becomes apparent when it is considered, first, that the leguminous plants, absorbing as they do ammonia in abundance by their leaves, can naturally dispense with a supply of this aliment to their roots; secondly, that of all the ingredients in the ash of the leguminosæ, lime and potash are the two most prominent; so that for soils abounding in lime (as cultivated soils for the most part do) potash remains, *conformably with Liebig's law*, the characteristic manure for the leguminosæ.

The root-crops, however, and particularly turnips, are brought forward as contradictory to Liebig's law, and confirmatory of the theory of manurial "specifics"; because, though the ash of the turnip contains more potash than phosphoric acid, this plant is nevertheless found to benefit, conversely, more by artificial supplies of phosphoric acid than of potash.

"It must be admitted," say the principal champions of the doctrine specific, "that the extraordinary effect of superphosphate of lime cannot be accounted for by the idea of merely supplying it in the actual constituents of the crop, but that it is due to *some special agency in developing the assimilative processes of the plant.*"* And again they say, "It is at any rate certain that phosphoric acid, though it forms so small a proportion of the ash of the turnip, has a very striking effect on its growth when applied as manure."†

On these statements it is first to be remarked that the experimental results on which they are founded, and which were obtained at Rothamstead, are at variance with those obtained on other soils by other equally trustworthy observers. According to the best analyses of the ash of turnips (swedes), these plants may be taken to contain about 0·1 per cent. of phosphoric acid. On the other hand, ordinary superphosphate of lime contains about 16 per cent. of this ingredient in the soluble form of combination; so that three cwt. of this manure contain between fifty-three and fifty-four lbs. of immediately-available phosphoric acid. Mr. J. Russell ‡ divided a turnip-field into plots: upon one plot he applied three cwt. of superphosphate; upon two others five cwt.; upon two others seven cwt. and ten cwt. respectively. On comparing the crops yielded by the two plots equally manured, a difference of 38 cwt. was observed between their respective weights. The figure fixes the limit of variation fairly attributable in this case, to causes other than the quantity of manure employed. The plot manured with three cwt. of superphosphate yielded to Mr. Russell 480 cwt. of swedes. These would

* On Agricultural Chemistry, especially in Relation to the Mineral Theory of Baron Liebig. Journ. Roy. Ag. Soc. of England, vol. xii, part i, 1851.

† Ibid.

‡ Journ. Roy. Ag. Soc., vol. xxii, p. 86.

contain in their ash, at the above-stated proportion of 0·1 per cent., just 53·76 lbs. of phosphoric acid; a result in curiously-close correspondence with the quantity of phosphoric acid contained in the superphosphate used. The mean yield of the two plots manured with five cwt. of superphosphate each did not differ from the yield of the plot manured with only three cwt. so much as the respective products of those two plots differed from each other. Hence it appears that the addition to the soil of a larger proportion of soluble phosphoric acid than the turnip-plants could consume had no "specific" influence in promoting their growth in this case. As for the crop of the plot manured with seven cwt. of superphosphate, it not only did not exceed, but fell short by a few cwt. of the mean yield of the plots manured with five cwt. each. A still further deficit, of a few cwts., was observed in the yield of the plot manured with ten cwt. of superphosphate. Both these deficienciés, however, were less than the difference of yield by the two plots equally manured. So that in this case, the yield of the plot which received in the manure the exact quantity of phosphoric acid removed in the crop was (within the limits of experimental error) equal to the yield of plots, respectively supplied with quantities 66 per cent, 133 per cent, and 233 per cent greater. Two plots which were left unmanured, on this occasion, for comparison's sake, gave a mean yield of only 330 cwt. of turnips per acre: being about one third less than the yield of the manured plots.

Hence it would appear that the turnip-plant benefits by an artificial supply of soluble superphosphate up to, but not beyond, the limit of its assimilating powers. And if it be admitted that the phosphates of the soil are in a less soluble state than the artificial superphosphate (a probable supposition), this case would seem to argue that the roots of the turnip, when simultaneously presented with different forms of phosphatic food soluble in different degrees, prefer the most soluble, and imbibe this first.

These results, in the reporter's judgment, stand in strong opposition to those obtained at Rothamstead, and tend to negative the view that phosphoric acid benefits turnips by some "specific agency," other than that due to it as a constituent of their ash.

The advocates of the "specific" doctrine, however, take up another ground. It is, they say, a universally recognized fact among farmers, that, in the ordinary course of husbandry, super phosphate—not potash—is the manure for turnips, though potash predominates over phosphoric acid in their ash. To quote their own language on this point, as given in the paper already referred to: "Common practice has," they say, "definitely determined in favor of phosphoric acid rather than of the alkalis, as the *special* manure to be provided for the turnip from sources external to the farm itself."

Admitting this case to be a very frequent one (it is certainly not universal), it appears to the reporter susceptible of an explanation, by which it falls, quite simple and readily, within the scope of Liebig's law.

For, in the ordinary course of rotation, cereals and root-crop follow each other, and alternately feed on the soil. Now the cereals, as every one knows, are greedy consumers of silica, partly for the coating of their grain, but principally for that of their straw. The cereals also assimilate phosphoric acid, and divide it in like manner between their grain and straw; this time however depositing it mostly in the grain. The silica and phosphates of the grain are, be it remembered, exported from the land. Of potash, the cereals are far less greedy than of phosphoric acid; and of the potash they do assimilate, the larger proportion is deposited in their straw, and returns in the dung to the soil. Keeping these facts in view, and considering also the original composition of fair arable soils, containing ordinary proportions of potassic silicates in course of gradual disintegration, it appears to the reporter that the cereals tend to withdraw the acid-ingredient of these silicates, leaving their alkaline bases as a bequest (so to speak) to the following generation of plants. Thus, when the root-crop enters into possession of the field, it meets with a soi recently drained of available phosphates, but not by any means exhausted of potash. What more natural, under such circumstances,—what more strictly conformable with Liebig's law,—than that soluble phosphates, not potash, should be the cinereal supply required?

Upon the whole, therefore, the reporter is constrained to believe that phosphoric acid is no more a "specific" (in any peculiar or mysterious sense) for the root-crops, than potash is for beans and peas, or nitrogen for corn. The more attentively, indeed, the facts are examined, the more strongly do they appear to confirm the grand and simple rule laid down by Justus Liebig, as the prime condition of sound and durable success in husbandry, viz., *the* *faithful restitution to the soil of the ash-constituents removed in the crops.*

Twelve years ago indeed, the leaders of the "nitrogen" school carried their doctrine so far as to declare ammonia a sufficient "substitute" for cinereal manures. "Even supposing," said they (writing in 1851)—"even supposing a mineral manure, founded on a knowledge of the ashes of plants, to be still the great desideratum, the farmer may rest contented meanwhile that he has in *ammonia*, supplied to him by Peruvian guano, by ammoniacal salts, and by other sources, SO GOOD A SUBSTITUTE."* The reporter does not hesitate to condemn the doctrine set up in this passage as one of unjustifiable spoliation.

Nine years later (in 1861)† the same writers tell the farmer that an ordinary corn-growing soil, taken as one foot deep, cultivated in the usual way, and annually exporting its whole produce of corn and meat, *without restitution of their cinereal constituents*, contains enough phosphoric acid to support this drain for 1000 years, enough potash to meet the demand for 2000 years, and enough silica to last for no less than 6000 years.

The evident tendency of these stupendous figures is to produce the impression that "restitution" to such a reservoir as this would be a mere absurdity. If the available cinereal treasures, lying within twelve inches under the soles of our feet, be really of this dazzling description, a proportionate supply of ammonia, to bring them as fast as possible into activity, may well be put forward as our chief agricultural requirement.

We are thus brought back to the nitrogen question; which, in the light of this doctrine of inexhaustibility, acquires a new and incommensurable importance. For, if we can only match our "inexhaustible" cinereals with a similar supply of ammonia, the lamp of Aladdin (so to speak) is at the disposal of mankind, and the language of Scheherzade is scarcely gorgeous enough to paint the golden future of our happy race.

To the momentous question thus raised, the prophets of cinereal plenty afford us, by their new mode of computation, the means of

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* 'On Agricultural Chemistry, especially,' &c., see the preceding note.

† 'On Some Points in Connection with the Exhaustion of Soils.' 'Report of the Brit. Assoc. for the Advancement of Science' for 1861.

making a most satisfactory reply. We know, from the results of numberless analyses of soils, that wheresoever we plunge a spade ten inches deep into an average arable soil, we intersect a layer of nitrogenous plant-food, held as "availably" as the cinereal stores, and sufficient in quantity to nourish good wheat-crops, year after year, *for upwards of seven centuries.*

To this magnificent nitrogenous reserve large-handed Nature liberally adds, out of our plenteous atmospheric stores, at least two thirds of the quantity annually required, even when this is calculated at the most liberal rate of farming; so that it will take 2100 years to exhaust our underground stock of nitrogen. If therefore we have, as we are assured, phosphates for 1000 years, our ammoniacal wealth (computed by the same rule) is fully twice as great; and these figures, be it observed, do not take into account (on either side) so much as a third of the depth really explored by the absorbent roots.

Why, then, do these annual wheat-crops refuse to grow? With all this ammonia lying amongst their roots. and with cinereal supplies in similar profusion, why are these corn-plants (to use the husbandman's metaphor) so "shy?" We turn naturally to the propounders of the "inexhaustible" theory for an explanation. Alas! we find that they studiously refrain from pressing the ammoniacal half of their argument. They place at our disposal phosphates for 1000 years, potash for twenty centuries, and silica for a threefold cycle of time; but of ammonia, by the same rule similarly abundant, they will not grant us one poor century's supply, *nor, indeed, a single year's.*

They supply us, instead, with the curious fact, that an artificial saline dressing, calculated to supply to a cornfield "100 lbs. of ammonia per acre," and "only increasing the percentage of ammonia in the soil by 0·0007,"—a chemically inappreciable addition,—will give "*a produce at least double that of the unmanured land.*"* Thus, with the ammonia of *centuries* crowded into a span-deep layer beneath our feet, we have still to go, money in hand, year by year, to the gas-works or the guano-stores for each succeeding crop's supply.

One consolation remains. Though ammonia, the "good substitute" for cinereals, is withheld, and the application of the "in-

* 'On Agricultural Chemistry,' &c., loc. prec.

exhaustible" theory to this, "the most precious" of plant-foods, is forbidden, we have still our grant of cinereal treasures to fall back on. To these, at least, the "inexhaustible" theory does apply; for are not its magnificent conclusions before us, stated in figures by its creators themselves?

There is in this much comfort. For, of the ammonia we need, Nature supplies, after all, the major part; whereas, of the cinereals, every ounce exported from the fields by man, must be by man, at his own cost, restored.

But this comfort also is snatched from us! Our gravely demonstrated cinereal wealth,—our "inexhaustible" treasure of silica, potash, and the phosphates, turns out to be as impalpable as the ammonia itself. Like conjurers' money, this treasure also vanishes out of our hands, even while we are trying to count it.

Who then deprives us of this, the remaining moiety of our agricultural fortune? Can it be that the theorists who gave it us, themselves also take it away? It is even so. The promulgators of the grand doctrine of cinereal affluence, caution us *not to act on it.* They tell us that they do not adopt it "in practice" for their own guidance; and we learn with sorrow, from their own pre-cited paper, the disastrous issue of an attempt, continued during eighteen years to carry it into effect:—

"They [the authors of the paper] had grown wheat for eighteen years consecutively on the same land, respectively without manure, with farm-yard manure, and with different constituents of manure, and they had determined the amounts of the different mineral constituents taken off in the crop from the respective plots. Numerous tables of the results were exhibited. * *

"Turning," they add, "to the bearing of the results on the main subject of inquiry, it appeared that when ammonia-salts were used alone, year after year, on the same land, the composition of the ash, both of the grain and straw, showed *an appreciable decline in the amount of phosphoric acid*, and that of the straw *a considerable reduction in the percentage of silica.*" Further on in the same paper, the farmer is told that the experimentalists "do not recommend such exhaustive practice as that quoted from their own experiments." Ten years previously (in 1851) the "inexhaustible" theory was in a more vigorous stage of its existence. Then the colossal reserves were only deemed liable to contingent exhaustion, in the double event, first of the discovery (not yet accomplished) of "a cheap source of ammonia"; and, secondly, of the "excessive" use of such newly-found nitrogenous supplies: in which case, said the theorists, "the available mineral [cinereal] constituents might, in their turn, become exhausted."—(*loc. prec.*)

Reverting to the paper of 1861 for one more quotation,—and it shall be the last,—the doctrine that nitrogen is a "specific" for corn, and a "good substitute" for cinereals, is, in tolerably explicit terms, abandoned by its authors themselves; who, after referring to the comparative crops they obtained by means of (1) *ammonia salts* alone, and (2) *mineral* [cinereal] constituents only, thus epitomise their experience:—

"But in neither of these cases was there anything like the amount of mineral constituents obtained in the crop, that there was when the ammonia-salts and mineral manures were used together, or when farm-yard manure was employed."

To sum this matter up in plain words: the "good substitute" for cinereals, put forth in 1851, has had a fair trial, and has failed. Ammonia, judged by the experiments of its advocates (as well as by many other trials), proves not to be, as was alleged, a "specific" manure for corn. The "specific" value of potash and the phosphates, for leguminous and root crops respectively, stands equally disproved. Corn and meat cannot be continuously exported from soils for 6000, 2000, or 1000 years, without restitution (respectively) of the silica, potash, and phosphates, removed in their tissues from the soils. These illusory views which their advocates (to do them justice) have already, to a large extent, honorably renounced, must be utterly abandoned. The celebrated "nitrogen theory" is at an end; and with it falls also the doctrine of "manurial specifics."

We now know that the costliest ammoniacal salt, and the cheapest and commonest of the cinereals (say for example silica or lime), judged by the spongiole of a plant's root, are of precisely equal value;—each priceless, so far as essential to the plant's nutrition; each worthless, as to every molecule beyond.

We know also that the great law of RESTITUTION applies equally to fixed and volatile, to scarce and to abundant, ingredients of plant-food; though the fulfilment of that law devolves unequally on man and nature, in every different case.

We know that the prosperity of the crop, which represents *dividend*, is but a delusive test of fertility, unless it be accompanied by the prosperity of the soil, which represents *capital*.

Every excess, whether on the side of expenditure or capitalization, whether on the side of over-cropping the land or of unduly augmenting its reserves, is equally a dereliction of agricultural duty, and equally reprehensible as a form of *waste*. For, if disproportionate expenditure dissipates the substance of wealth in space, disproportionate capitalization (the miser's fault) squanders its usufruct in time. It is therefore our duty to call forth and consume the largest crops we can; but only and always on the condition of not infringing on the reserves of the soil. If, through indolence, we fail to produce the largest possible supply of food for the consumption of the present generation, we retard, *pro tanto*, the multiplication of our race, and fail in our duty to the unborn. If, on the other hand, greed of immediate gain tempt us to reduce the mineral balance in the soil (of which, be it, remembered, we are not *owners* but *trustees*), we equally sin against the unborn, by devouring their inheritance. We owe to our fathers, and we are bound to pay to our children, who are also theirs, a double debt,—life. and the means of its support. A generous race as scornfully disdains to hand down to its posterity an impoverished soil, as a degenerate blood. The nitrogen theory failed to recognize these principles, and hence its downfall.

SEWAGE-MANURE EXPERIMENTS AT RUGBY.—If, from the point of view now reached, attention be given to the course of experiments recently undertaken, and still in progress, at Rugby, to determine the value of sewage-manure, it will be readily perceived that these experiments are based on a misconception, as well of the problem to be solved, as of the experimental method which alone is adequate to its conclusive solution.

The nature of this twofold misconception is sufficiently manifested in the tests of value exclusively appealed to in these trials. These tests are, on the one hand the quantity, and on the other hand the quality, of the crops raised upon measured areas of land, under the influence of different volumes of sewage, as compared with the yield of a similar area kept purposely unmanured.

A few years ago this method would have met with very general approbation and concurrence. But in the present state of agricultural knowledge its fallacy will be readily perceived. We are now aware that the value of a manure does not bear any such fixed and exclusive relation, as the method in question supposes, to its immediate influence on the crop. The reader who has accompanied the reporter through the foregoing pages of this section will be prepared to recognize that, under conditions of frequent occurrence, a luxuriant crop, obtained by the use of an artificial manure, so far from manifesting increased fertility, may but be the sign and measure of accelerated exhaustion. He will also understand that a manure may have added not a single sheaf to the harvest, not so much as one blade to the yield of hay, and yet may have solved the great problem of agriculture, by exactly balancing the drain made on the soil by the crop.

An unlimited supply of the former manure might be a positive curse to a nation, by tempting them unduly to exhaust their soil. The gratuitous gift of the latter, on the contrary, in due adaptation to every field, would be the most precious boon a nation could receive; because it would place their agriculture on a footing of perdurable prosperity.

It may however be urged that the object of the Rugby experiments is simply to determine the intrinsic value of the Rugby sewage; meaning its degree of richness in available plant-food of all kinds, or its absolute crop-increasing power. And this information, it may be contended, the direct test to which the sewage is brought at Rugby (and which may be compendiously termed the *crop-test*), seems, at all events, well adapted to elicit.

But a very brief consideration of the matter, in the light of the above-stated principles, will suffice to show that these reasonings also are illusory; and that the crop-test, of itself, cannot afford any reliable or conclusive information as to the crop-increasing power of sewage.

For the benefit resulting to any given crop, from the use of any given manure, will vary from absolutely *nil* up to the maximum attainable effect, according to the nature and composition of the soil, which, in the Rugby experiments, does not appear to have been determined. The richer the soil of the experimental fields, the poorer must the Rugby sewage seem; because, however rich this sewage may be, the increase it can determine in the crop depends, not merely on the wealth it brings, but also on the want which it supplies.

The blowing sands at Craigentinny, manured with the Edinburgh sewage, want every form of plant-food but silica, and contain even that only in its insoluble variety. It is, accordingly, on these sands that the richest increase ever obtained by means of sewage has been achieved. It is impossible to infer from this increase what the effect of the Edinburgh sewage would be on the grass-crop of the Rugby meadows; or on any other crop elsewhere. Still less can the crops obtained, either at Craigentinny or Rugby, afford of themselves the slightest indication of the *area* to which the sewage of the British population is due.

It is not necessary, and it might seem invidious, to pursue these reasonings further, or to trace in minuter detail the erroneous conditions, which involve in doubt, and render inconclusive, the trials in progress at Rugby. Those trials are carried on by a body of able men, who will doubtless improve their method as they proceed. The reporter however is anxious, in quitting this subject, to record his conviction that no experiments on sewage can determine its value, or settle the problem of its utilization, unless the measurement of its influence on the *crop* be conjoined with that of its effect on the *soil;* unless, in other words, the maintenance of capital receive a share of attention, as well as the increase of expenditure; unless, to sum up all, we approach this question, not merely in the hope of advantage to ourselves, but also under a deep sense of our duty to posterity.

Tribute to Messrs. Lawes and Gilbert.—Having spoken in condemnatory terms of the "nitrogen theory," and of the doctrine of "manurial specifics," and having declared these theories, to the best of his judgment, defunct, the reporter is anxious in justice to add, that their career, if brief, has been brilliant; that they have been advocated courageously and conscientiously, in single desire to arrive at the truth; and that the princely experiments undertaken for their support, if they have failed in establishing untenable propositions, have nevertheless elicited incidental and collateral results, of very high interest and importance. Twenty years of indefatigable labor in a difficult field of research entitle Messrs. Lawes and Gilbert to an ample tribute of public recognition. It is indeed impossible to believe that reasoners so acute, and experimentalists so persevering, will long continue to maintain the slightest remnants of a doctrine so manifestly opposed to the laws of nature. In this respect their eminent antagonist, who, in 1845, found himself in a similar predicament,—*i. e.*, in unwitting opposition to a law of nature (as above explained),—has set a noble example.

HOMAGE TO JUSTUS LIEBIG.—The correction of his error by Way, Liebig frankly and unhesitatingly accepted. His genius instantly appreciated the value of the English chemist's observation; and shed upon it so bright a light as may be said to have doubled its importance. Liebig, in fact, studied the new truth in all its bearings, supplied its most generally-received interpretation, displayed its momentous consequences, elevated it to the rank of a law of nature, and embodied this law as one of the corner-stones of his great edifice.

Probably, in all Liebig's illustrious career, no incident bears higher testimony than this to the vigor and fertility of his intellect, to his undeviating candor, and to his disinterested solicitude, on all occasions, for truth and truth alone.

The writer would, indeed, be doubly untrue to his functions as reporter on this occasion, and to his feelings as Liebig's countryman and former pupil, if he failed to acknowledge here, in a few words uttered from his heart, the debt of Europe—nay, of mankind at large—to the illustrious regenerator of agriculture. Continuing the work of his revered predecessors, Lavoisier and Sir Humphrey Davy, Liebig has nobly trod the arduous path which it was their glory to point out. And, side by side, as long as husbandry shall last, will these three names shine in co-equal glory,—ANTOINE LAVOISIER, HUMPHREY DAVY, JUSTUS LIEBIG. To Lavoisier belongs the noble initiation of the work; to Davy, its splendid prosecution; to Liebig, its glorious consummation. Embracing in his masterly induction the results of all foregone and contemporary investigation, and supplying its large defects by his own incomparable researches, Liebig has built up on imperishable foundations, as a connected whole, the code of simple general laws on which regenerated agriculture must henceforth for all time repose.

In speaking thus of his illustrious countryman and revered master, the reporter does not fear to be misunderstood. No narrow spirit of patriotism animates his words. Genius, indeed, in its highest manifestations, transcends mere national boundaries; kingdoms are too narrow to be its birthplace; and in the homage it receives, not this or that country, or continent, or hemisphere, but humanity at large, is exalted.

NATURAL HISTORY SOCIETY.

ANNUAL MEETING.

The annual meeting of the Society was held in its rooms on the evening of May 18th, Principal Dawson, President, in the chair. A large number of the members were present. Mr. J. F. Whiteaves, the Recording Secretary, read the minutes of the last annual meeting; after which the usual annual address of the President was read, as follows:—

ADDRESS OF THE PRESIDENT.

GENTLEMEN,—I labor on this occasion under the disadvantage of having had twice in succession to prepare the annual address of the President; a circumstance which should not ordinarily occur in a society of this character, in which, following the usage of our older sisters, we should endeavor to have a new mind brought to bear on this work in each successive year. I shall however take advantage of this circumstance to deviate somewhat from the course usual with us on such occasions, and, after merely glancing at the scientific work of the Society, to direct your attention to some speculations of my own on subjects now attracting the attention of naturalists.

The scientific papers laid before this Society in its session just concluded, if not quite so numerous as in some previous sessions, are not inferior in point of interest and importance. In geology, Sir William Logan has continued in our journal the discussion of the age and distribution of the Quebec Group of Rocks. Dr. Hunt has given further and important facts in chemical geology. Professor Bell has illustrated certain portions of the superficial deposits, and has described one of our most important quarries of roofing-slate. Mr. McFarlane has contributed an elaborate discussion of the interior condition of our planet and of the mode of formation of Metamorphic and Igneous Rocks. Professor Bailey has elucidated an obscure portion of the Geology of New Brunswick, indirectly of much interest to Canadian geologists. Mr. Billings has contributed a paper on a disputed genus of Brachiopods. Professor How has given us Analyses of Mineral Waters in Nova Scotia. Mr. Jones has sent us an interesting paper on the geological importance of Ocean Currents. I have myself occupied some space in our proceedings with my researches on Reptiles and Plants of the Coal-Period; and in connection with these, I would desire to say here that I regard the conclusions of Dr. Hunt in his short but valuable paper on the Climate of the Palæozoic period as of great importance. Whatever views we may adopt as to the original heated condition of the earth, if we take into account the enormous length of time required by the calculations of physicists * for the reduction of the earth's temperature even one degree, it seems chimerical to suppose that any appreciable effect on climate could have been produced by internal heat in the coal-period. Yet the character and distribution of the flora of that period would appear to imply a comparatively high and equable temperature in the northern temperate and sub-arctic zones. Now if the experiments of Tyndall, cited by Dr. Hunt, can be taken to establish that a small percentage of carbonic acid and an additional amount of aqueous vapour diffused through the atmosphere would largely economise the solar heat by preventing radiation, and thus give conditions similar to those of a glass-roofed conservatory, we have in this consideration, in connection with the known distribution of land and water in the carboniferous era, a sufficient cause for any difference of climatal conditions required by the flora. To appreciate more fully the value of this suggestion, it would be necessary to make experiments as to the amount of carbonic acid which might be beneficially present in the air, in the case of plants like those of the coal-period, for instance Ferns, *Lycopodiaceæ* and *Cycadacæ*, and also to calculate the effect of such proportion of carbonic acid in impeding radiation.

Before leaving the work of the Society in the past year, I must not omit to mention that we have not neglected zoölogy and botany; and among contributions of this kind I could have wished to notice at some length those of Mr. Packard on the Marine Invertebrates of Labrador, and of Professor Lawson on Canadian Botany.

* For example, those of Poisson and Hopkins, which would give 100,000,000,000 of years for a diminution of one to three degrees of temperature.

By far the most important publication of the past year, in the Natural History of Canada, has been the great Report of the Geological Survey, a work in which, as the achievement of members of this Society, we may very well take pride; and on which we may congratulate ourselves as facilitating the labors of those among us who pay attention to geology, either with a view to practical or scientific results, and as greatly raising the scientific reputation of this country.

The Report of the Survey has already been reviewed in the *Naturalist*, and I propose here not so much to say anything as to its general merits, as to refer to a few points in Canadian geology to which it directs our attention.

One of these is the discovery of fossils in the old Laurentian rocks, heretofore usually named *Azoic*, as being destitute of life, and much older than any rocks known to contain fossils. The oldest remains of living beings, until this discovery, had been found in rocks known as Cambrian, or Primordial, and equivalent in age to our oldest Silurian of Canada, or at the most to our Huronian. But the Huronian series in Canada rests on the upturned edges of the Laurentian, which had been hardened and altered before the Huronian series was deposited. Again, Sir William Logan has shown that the Laurentian system itself contains two distinct series of beds, the upper of which rests unconformably on the lower. There are thus in Canada at least two great series of rocks, of such thickness as to indicate two distinct periods each of vast length, below the lowest fossiliferous rocks of other countries. Yet in the lowest of these so-called Azoic groups fossils have now been found; Canada thus distancing all other parts of the world, so far as yet known, in the antiquity of its oldest fossils.

I have had the happiness to submit these remarkable specimens to microscopic examination, at the request of Sir W. E. Logan, and have arrived at the conclusion that they are of animal nature, and belong to the very humblest type of animal existence known, that of the *Rhizopods*, though they far outstrip in magnitude any known modern representatives of that group. The discovery of this remarkable fossil, to be known as the *Eozoön Canadense*, will be one of the brightest gems in the scientific crown of the Geological Survey of Canada.

In connection with this subject, it is to be observed that the grand order of succession in the Laurentian system seems to be the same with that so often repeated in other parts of the geological scale,—coarse fragmentary beds represented by conglomerate and gneiss; calcareous and fossiliferous bands represented by the Eozoön limestones; and finer earthy deposits, represented by felspathic rocks. This brings the Laurentian into a cycle somewhat similar to that of the Potsdam sandstone, the Chazy and Trenton limestone, and the Utica slate and Hudson River in the Lower Silurian; or to that of the Medina sandstone, the Niagara limestone, and Lower Helderberg in the Upper Silurian; or to that of the Oriskany sandstone, Corniferous limestone, and Hamilton and Chemung groups in the Devonian; or to that of the Lower Carboniferous conglomerates and sandstones, the Carboniferous limestones, and the Coal-measures in the Carboniferous period. This recurrence of cycles of deposit cannot be accidental. It is more or less to be seen throughout the geological scale, and in all countries; and as I have elsewhere pointed out, it includes numerous subordinate cycles within the same formation, as in the coal-measures. Eaton, Hunt, and Dana have referred to it; but it deserves a more careful study as a means of settling the sequence of oscillations of land and water in connection with the succession of life. It will also be important in giving fixity to our geological classifications, and may eventually aid in establishing more precise views of the dynamics of geology and of the lapse of geological time. The progress of the earth has, like most other kinds of progress, been not by a continuous evolution, but by a series of cycles, of great summers and winters, or days and nights, of physical and vital changes, in each of which all things seem to revolve back to the place of beginning; only to begin a new cycle or new turn of a spiral, similar to the last in its general course, though altogether different in its details, accompaniments, and results.

There is another subject of great geological importance on which the publication of the Report enables strong ground to be taken. I refer to the conditions under which the *Boulder-Drift* of Canada was deposited. It has been customary to refer this to the action of ice-laden seas and currents, on a continent first subsiding and then re-elevated. But this opinion has recently been giving way before a re-assertion of the doctrine that land-glaciers have been the principal agents in the distribution of the boulder-drift, and in the erosions with which it was accompanied. I confess that I have steadily rejected this last doctrine; being convinced that insuperable physical and meteorological objections might be urged against it, and that it was not in accordance with the facts which I had myself observed in Nova Scotia and in Canada. The additional facts contained in the present Report enable me to assert with confidence, though with all humility, that glaciers could scarcely have been the agents in the striation of Canadian rocks, the transport of Canadian boulders, or the excavation of Canadian lake-basins. In making this statement I know that I differ in some degree from many of my geological friends, but I know that they will be rejoiced that I should freely and frankly state the reasons of my belief.

The facts to be accounted for are the striation and polishing of rock-surfaces, the deposit of a sheet of unstratified clay and stones, the transport of boulders from distant sites lying to the northward, and the deposit on the boulder-clay of beds of stratified clay and sand, containing marine shells. The rival theories in discussion are—*first*, that which supposes a gradual subsidence and re-elevation, with the action of the sea and its currents, bearing ice at certain seasons of the year; and, *secondly*, that which supposes the American land to have been covered with a sheet of glacier several thousands of feet thick.

The last of these theories, without attempting to undervalue its application to such regions as those of the Alps or of Spitzbergen or Greenland, has appeared to me inapplicable to the drift-deposits of eastern America, for the following among other reasons:

1. It requires a series of suppositions unlikely in themselves and not warranted by facts. The most important of these is the coincidence of a wide-spread continent and a universal covering of ice in a temperate latitude. In the existing state of the world, it is well known that the ordinary conditions required by glaciers in temperate latitudes are elevated chains and peaks extending above the snow-line; and that cases in which, in such latitudes, glaciers extend nearly to the sea-level, occur only where the mean temperature is reduced by cold ocean-currents approaching to high land, as for instance in Terra del Fuego and the southern extremity of South America. But the temperate regions of North America could not be covered with a permanent mantle of ice under the existing conditions of solar radiation; for even if the whole were elevated into a table-land, its breadth would secure a suffi-

cient summer heat to melt away the ice, except from high mountain-peaks. Either then there must have been immense mountain-chains which have disappeared, or there must have been some unexampled astronomical cause of refrigeration, as, for example, the earth passing into a colder portion of space, or the amount of solar heat being diminished. But the former supposition has no warrant from geology, and astronomy affords no evidence for the latter views, which besides would imply a diminution of evaporation militating as much against the glacier-theory as would an excess of heat. An attempt has recently been made by Professor Frankland to account for such a state of things by the supposition of a higher temperature of the sea, along with a colder temperature of the land: but this inversion of the usual state of things is unwarranted by the doctrine of the secular cooling of the earth; it is contradicted by the fossils of the period, which show that the seas were colder than at present; and if it existed, it could not produce the effects required, unless a preternatural arrest were at the same time laid on the winds, which spread the temperature of the sea over the land. The alleged facts observed in Norway, and stated to support this view, are evidently nothing but the results ordinarily observed in ranges of hills, one side of which fronts cold sea-water, and the other land warmed in summer by the sun.

2. It seems physically impossible that a sheet of ice, such as that supposed, could move over an uneven surface, striating it in directions uniform over vast areas, and often different from the present inclinations of the surface. Glacier-ice may move on very slight slopes, but it must follow these; and the only result of the immense accumulation of ice supposed, would be to prevent motion altogether by the want of slope or the counteraction of opposing slopes, or to induce a slight and irregular motion toward the margins or outward from the more prominent protuberances.

It is to be observed, also, that, as Hopkins has shown, it is only the *sliding* motion of glaciers that can polish or erode surfaces, and that any internal changes resulting from the mere weight of a thick mass of ice resting on a level surface, could have little or no influence in this way.

3. The transport of boulders to great distances, and the lodgment of them on hill-tops, could not have been occasioned by glaciers. These carry downward the blocks that fall on them from wasting cliffs. But the universal glacier supposed could have no such

cliffs from which to collect; and it must have carried boulders for hundreds of miles, and left them on points as high as those they were taken from. On the Montreal Mountain, at a height of 600 feet above the sea, are huge boulders of feldspar from the Laurentide hills, which must have been carried 50 to 100 miles from points of scarcely greater elevation, and over a valley in which the striæ are in a direction nearly at right angles with that of the probable driftage of the boulders. Quite as striking examples occur in many parts of this country. It is also to be observed that boulders, often of large size, occur scattered through the marine stratified clays and sands containing sea-shells; and whatever views may be entertained as to other boulders, it cannot be denied that these have been borne by floating ice. Nor is it true, as has been often affirmed, that the boulder-clay is destitute of marine fossils. At Murray Bay and St. Nicholas, on the St. Lawrence, and also at Cape Elizabeth, near Portland, there are tough stony clays of the nature of true "till," and in the lower part of the drift, which contain numerous marine shells of the usual Post-pliocene species.

4. The Post-pliocene deposits of Canada, in their fossil remains and general character, indicate a gradual elevation from a state of depression, which on the evidence of fossils must have extended to at least 500 feet, and on that of far-travelled boulders to nearly ten times that amount. while there is nothing but the boulder-clay to represent the previous subsidence, and nothing whatever to represent the supposed previous ice-clad state of the land, except the scratches on the rock surfaces, which must have been caused by the same agency which deposited the boulder-clay.

5. The peat deposits with fir-roots, found below the boulder-clay in Cape Breton, the remains of plants and land-snails in the marine clays of the Ottawa, and the shells of the St. Lawrence clays and sands, show that the sea at the period in question had much the temperature of the present arctic currents of our coasts, and that the land was not covered with ice, but supported a vegetation similar to that of Labrador and the north shore of the St. Lawrence at present. This evidence refers not to the later period of the Mammoth and Mastodon, when the re-elevation was perhaps nearly complete, but to the earlier period contemporaneous with or immediately following the supposed glacier-period. In my former papers on the Post-pliocene of the St. Lawrence, I have

shown that the change of climate involved is not greater than that which may have been due to the subsidence of land, and to the change of course of the Arctic current, actually proved by the deposits themselves.

These objections might be pursued to much greater length; but enough has been said to show that there are in the case of northeastern America, strong reasons against the existence of any such period of extreme glaciation as supposed by many geologists; and that if we can otherwise explain the rock striation and polishing, and the formation of fiords and lake-basins, the strong points with these theorists, we can dispense altogether with the portentous changes in physical geography involved in their views, and which are not necessary to explain any of the other phenomena.

It is on these points more especially, that the Report of the Geological Survey throws new light; though Sir William, with his usual caution, has not committed himself to theoretical conclusions; and in one or two local cases he seems to favor the glacier theory. It has long been known to geologists, that in northeastern America, two main directions of striation of rock-surfaces occur, from northeast to southwest, and from northwest to southeast; and that locally the directions vary from these to north and south and east and west. Various attempts have been made, but without much success, to account for these directions of striation by the motion of glaciers; and while it is quite easy for any one prepossessed with this view to account in this way for the striation in a particular valley or part of a valley, yet so may exceptional facts occur as to throw doubt on the explanation, except in the case of a few of the smaller and steeper mountain-gorges.

In the Report of the Survey of Canada a valuable table of these striations is given, from which it appears that they are locally distributed in such a way as to throw a decided gleam of light on their origin.

It would seem that the dominant direction in the valley of the St. Lawrence, along the high lands to the north of it, and across western New York, is northeast and southwest; and that there is another series of scratches running nearly at right angles to the former, across the neck of land between Georgian Bay and Lake Ontario, down the valley of the Ottawa, and across parts of the Eastern Townships, connecting with the prevalent southeast striation which occurs in the valleys of the Connecticut and Lake Champlain, and elsewhere in New England. What were the determining conditions of these two courses, and were they contemporaneous or distinct in time? The first point to be settled in answering these questions, is the direction of the force which caused the striæ. Now, I have no hesitation in asserting, from my own observations as well as from those of others, that for the southwest striation the direction was *from the ocean toward the interior, against the slope of the St. Lawrence valley.* The crag-and-tail forms of all our isolated hills, and the direction of transport of boulders carried from them, show that throughout Canada the movement was from northeast to southwest.* This at once disposes of the glacier-theory for the prevailing set of striæ; for we cannot suppose a glacier moving from the Atlantic up into the interior. On the other hand, it is eminently favorable to the idea of ocean drift. A subsidence of America, such as would at present convert all the plains of Canada and New York and New England into sea, would determine the course of the Arctic current over this submerged land from northeast to southwest; and as the current would move *up a slope*, the ice which it bore would tend to ground, and to grind the bottom as it passed into shallower water; for it must be observed that the character of slope which enables a glacier to grind the surface, may prevent ice borne by a current from doing so, and *vice versa.*

Now we know that in the Post-pliocene period eastern America was submerged, and consequently the striation at once comes into harmony with other geological facts. We have of course to suppose that the striation took place during submergence, and that the process was slow and gradual, beginning near the sea and at the lower levels, and carried upwards to the higher grounds in successive centuries, while the portions previously striated were covered with deposits swept down from the sinking land or dropped from melting ice. It would be easy to show that this view corresponds with many of the minor facts.

Farther, the facts thus ascertained account for the excavation of the deep and land-locked basins of our great American lakes. Ocean currents, if cold, and clinging to the bottom, must cut out pot-holes, just as rivers do, though geologists are too apt to limit their function to the throwing up of banks. The course

* The few exceptional cases appear to belong mostly to the later period of the stratified sands.

of the present arctic current along the American coast has its deep hollows as well as its sand-banks. Our American lake-basins are cut out deeply into the softer strata. Running water on the land would not have done this, for it could have no outlet; nor could this result be effected by breakers. Glaciers could not have effected it; for even if the climatal conditions for these were admitted, there is no height of land to give them momentum. But if we suppose the land submerged so that the Arctic current, flowing from the northeast, should pour over the Laurentian rocks on the north side of Lake Superior and Lake Huron, it would necessarily cut out of the softer Silurian strata just such basins, drifting their materials to the southwest. At the same time, the lower strata of the current would be powerfully determined through the strait between the Adirondac and Laurentide hills, and, flowing over the ridge of hard rock which connects them at the Thousand Islands, would cut out the long basin of Lake Ontario, heaping up at the same time in the lee of the Laurentian ridge, the great mass of boulder-clay which intervenes between Lake Ontario and Georgian Bay. Lake Erie may have been cut by the flow of the upper layers of water over the Middle Silurian escarpment; and Lake Michigan, though less closely connected with the direction of the current, is, like the others, due to the action of a continuous eroding force on rocks of unequal hardness.

The predominant southwest striation, and the cutting of the upper lakes, demand an outlet to the west for the Arctic current. But both during depression and elevation of the land, there must have been a time when this outlet was obstructed, and when the lower levels of New York, New England, and Canada were still under water. Then the valley of the Ottawa, that of the Mohawk, and the low country between Lakes Ontario and Huron, and the valleys of Lake Champlain and the Connecticut, would be straits or arms of the sea, and the current, obstructed in its direct flow, would set principally along these, and act on the rocks in north and south and northwest and southeast directions. To this portion of the process I would attribute the northwest and southeast striation. It is true that this view does not account for the southeast striæ observed on some high peaks in New England; but it must be observed that even at the time of greatest depression, the Arctic current would cling to the northern land, or be thrown so rapidly to the west that its direct action might not reach such summits.

Nor would I exclude altogether the action of glaciers in eastern America, though I must dissent from any view which would assign to them the principal agency in our glacial phenomena. Under a condition of the continent in which only its higher peaks were above the water, the air would be so moist, and the temperature so low, that permanent ice may have clung about mountains in the temperate latitudes. The striation itself shows that there must have been extensive glaciers as now in the extreme Arctic regions. Yet I think that most of the alleged instances must be founded on error, and that old sea-beaches have been mistaken for moraines. I have failed to find even in the White Mountains any distinct sign of glacier action, though the action of the ocean-breakers is visible almost to their summits; and though I have observed in Canada and Nova Scotia many old sea-beaches, gravel-ridges, and lake-margins, I have seen nothing that could fairly be regarded as the work of glaciers. The so-called moraines, in so far as my observation extends, are more probably shingle beaches and bars, old coast-lines loaded with boulders, trains of boulders or "ozars." Most of them convey to my mind the impression of ice-action along a slowly subsiding coast, forming successive deposits of stones in the shallow water, and burying them in clay and smaller stones as the depth increased. These deposits were again modified during emergence, when the old ridges were sometimes bared by denudation, and new ones heaped up.

I shall close these remarks, perhaps already too tedious, by a mere reference to the alleged prevalence of lake-basins and fiords in high northern latitudes, as connected with glacial action. In reasoning on this, it seems to be overlooked that the prevalence of disturbed and metamorphic rocks over wide areas in the north is one element in the matter. Again, cold Arctic currents are the cutters of basins, not the warm surface-currents. Further, the fiords on coasts, like the deep lateral valleys of mountains, are evidences of the action of the waves rather than of that of ice. I am sure that this is the case with the numerous indentations of the coast of Nova Scotia, which are cut into the softer and more shattered bands of rock, and show, in raised beaches and gravel ridges like those of the present coast, the levels of the sea at the time of their formation.

In conclusion, allow me to express my regret that the pressure of other occupations has allowed me so little time to discharge my duties as your president, and to hope that the course of the Society in the coming year may be still more prosperous and successful than in the past.

REPORT OF THE COUNCIL.

The Council of the Montreal Natural History Society, at their thirty-sixth annual meeting, and in conformity with their prescribed duty and the yearly custom, beg to lay before its members an account of their proceedings during their tenure of office, which this evening brings to a close: and in so doing have much pleasure to congratulate its members on the steady and onward progress which has characterized the proceedings of the past year.

The Museum.

The donations to the Museum have been numerous and valuable; and your Council would more especially acknowledge donations from the University of our sister city, the Laval University; of some 418 species of insects from Mr. Saunders of London, C.W.; also donations from our worthy president, Dr. Dawson, consisting of fishes and shells; several birds, and three cases of insects from Mr. Ferrier, our treasurer; and some valuable donations from Mr. Barnston; besides several small donations from other parties, which though not so numerous, are not the less valuable A list of these will be found appended to this report.

Your Council would beg to make special mention of the Scientific Curator, Mr. Whiteaves, who continues to give the most entire satisfaction. His work has been onerous and difficult. An inspection of the Museum will at once convince any one of the labor and care he has bestowed on the classification and labelling of the specimens in each department of Natural History. And your Council would congratulate the Society on this judicious and efficient appointment.

The Library.

The donations to the Library have not been very numerous; the completion of Silliman's Journal (by purchase), and the usual exchanges from sister Societies form by far the greatest feature on the list of new books. The Council cannot but express its regret, that, owing to the want of funds, few new purchases have been able to be made. Notwithstanding, valuable donations of some twenty-four volumes have been received from the Literary and Historical Society of Quebec; and your Council have again to record the generosity of Mr. Ferrier, our treasurer, who has also presented some eleven or twelve volumes.

Original Papers Read.

During the past season twenty-four original papers have been read and discussed on the various departments of Natural History, viz., Geology, Zoology, and Botany. Most of these papers have been published in The Canadian Naturalist; which, besides being the record of our own transactions here, is the means of disseminating and spreading an account of our proceedings to other countries; and your Council cannot but regard this publication as an important feature in our future progress and usefulness.

Owing to the liberality of the publishers, Messrs. Dawson Brothers, The Canadian Naturalist has become second to no other publication of a like nature, containing, as it does, a great amount of useful and scientific knowledge. The Editing Committee deserve from your Council special mention for their successful labors in this important department.

Public Lectures.

The annual course of Sommerville Lectures was delivered in the Lecture Hall of the Society, to very large and respectable audiences. The following form the subjects of the course:—

First Lecture—18th February 1864, by W. Hingston, M.D., F.R.C.S.E., "On the Harmony observed in Nature."

Second Lecture—25th February, by Charles Smallwood, M.D., LL.D., "On Terrestrial Magnetism."

Third Lecture—3d March, by H. B. Small (Lin. Coll. Ox.), "On a Trip to our Satellite."

Fourth Lecture—10th March, by James Pech (Mus. Doc.), "On Music and the People."

Fifth Lecture—17th March, by T. Sterry Hunt, M.A., F.R.S., "On the Correlation of Forces."

Sixth and concluding Lecture on the 24th March, by Dr. Dawson, F.R.S., F.G.S., &c., (the President,) "On Man's Place in Nature."

CONVERSAZIONE.

The second annual conversazione was held in the Society's rooms on the evening of the 2nd of February, and was, as on a former occasion, very well attended. Some works of art were exhibited, and also several microscopes and other philosophical instruments. A variety of very successful chemical experiments were shown by Prof. Robbins; and dissolving views were also kindly exhibited by Mr. C. Hearn, optician. Addresses were delivered by the President, Dr. Dawson, Hon. Mr. Sheppard, and Professor Miles. Efforts on the part of your Council were made to secure several scientific and literary friends from a distance, but who, from various causes, could not be present. The Hon. Mr. Sheppard of Drummondville, and Professor Miles of Lennoxville College, were the only two gentlemen who kindly assisted on the occasion.

Your Council would also beg to mention, that, owing to the kindness of Col. Dunlop, the Band of the Royal Artillery performed some choice pieces of music during the evening.

The success of these re-unions has been very decided; and your Council fondly hope, that they have proved a source of great intellectual enjoyment to those persons present, and which they trust will tend to prove the increasing desire on the part of the citizens of Montreal generally for the attainment of a knowledge of Natural History and its kindred sciences.

In connection with this subject your Council would state, that a Course of twelve Lectures on Geology, and twelve on Botany, were delivered by Mr. Whiteaves in the rooms of the Society and under its auspices during the past winter, at a reduced charge to members of the Society. The results were satisfactory, and some additional members were thus obtained, and some few donations to the library.

MISCELLANEOUS.

Your Council, in accordance with the desire of the Society, have caused the silver medal to be transmitted to Dr. Daniel Wilson of Toronto, bearing an appropriate inscription, to which Dr. Wilson has returned a very suitable and feeling reply.

And your Council, in furtherance of the objects of the Society, and in accordance with its constitution, would recommend that the Society's silver medal for this year be presented to Sir W. E. Logan, one of the early and very active members of the Society, and who has so long and so well labored in developing the vast geological and mineral resources of Canada; and your Council would suggest that the present time seems a very appropriate one, on the occasion of the publication of his general work on Canadian Geology.

Some defects in the chimneys (caused by the method of warming the rooms of the Society) gave rise to some necessary repairs (which were stated to be of frequent occurrence); and it was deemed advisable to consult with Messrs. Prowse & McFarlane as to the cheapest and best way of keeping the rooms warm during the winter months. It was thought desirable to erect a hot-air furnace; but action in this matter was not taken until somewhat late in the season, which consequently incurred a somewhat large expenditure for coal, which will be obviated in future, by purchasing it at an earlier period. A contract was entered into with Messrs. Prowse & McFarlane, who, in a most generous and liberal spirit, offered to give a long credit if required, for the cost of its erection. Your Council fully believe that in the end it will effect a considerable saving. Double windows are also required, at a cost of about $100. Your Council would respectfully urge this on the attention of their successors.

New cases have been made for the reception of the mammals, and also a cabinet for the collection of insects. Some new cases have been set up for the reception of specimens of Canadian fishes, also four or five additional cases for birds. Much remains to be done in this department, and a still greater want of proper cases and cabinets for the reception of the numerous specimens already classified.

Your Council would beg to tender to Mr. Ferrier, the treasurer, the thanks of the Society for the liberality with which he has at all time made advances for the purposes of liquidating the more urgent demands of the current expenses of the Society. Your Council would also bear a willing testimony to the efficiency of Mr. Hunter, who has discharged his duties with satisfaction : and it is pleasing to be able to testify to his obliging and kind manner on all occasions, and also to make mention of many specimens of fishes and birds furnished by him to the Museum.

The Council would also report that they have received a grant of money (though of smaller amount than in any previous year) from the Government for the past year; and would also further state with regret, that no action has at present been taken to discharge the debt still due by the Society.

During the past winter your Council have permitted the Numismatic Society and the Montreal Literary Club to hold their meeting in their rooms on evenings not specially devoted to our own Society, and at a reasonable rate for fuel and light.

Your Council would further suggest, and in accordance with the amended act of Parliament, that the number of Vice-Presidents should not exceed nine, and that the Council should also consist of nine members.

Your Council would beg leave further to state, that they have received a communication from Mr. Leeming, calling attention to the fact that the remains of the late Rev. Mr. Sommerville are at present in the old Protestant burying-ground in Dorchester street, and calling on the Society to assist, conjointly with the Corporation of the Montreal General Hospital, the Trustees of St. Gabriel Church, and a clergyman now resident in Quebec, for the removal of the body to the Mount Royal Cemetery, and also the Monument at present erected over his remains. Your Council would therefore suggest that some action be taken in this matter at as early a period as possible.

They have also received a communication from the Board of Arts and Manufactures, in which it sets forth that it has "in its hands a considerable property, subject to a ground-rent, and burthened with hypotheques so large as to consume all its annual grant, and render the Board unable to carry on its proper operations, viz., to increase and maintain its free Library, to establish and keep up a Museum of Industrial Products, and to promote the education of mechanics and artizans.

"The property thus held has been set apart for the use of scientific and literary bodies who might wish to erect buildings for their accommodation, having been acquired with a view to such uses. In fact the Board has considered itself, in some sort, a trustee for these other public bodies, either existing or projected. But the members of the Board, hitherto disappointed of relief from the Provincial Government, feel that they cannot continue to hold this property for a much longer period, at a cost so great as the abdication of their own functions under the statute, and are therefore desirous, as speedily as possible, to come to an arrangement—if it be possible—with your own and other societies, by which a building-site may be transferred to you on easy terms, and co-operation secured between the Society and this Board in promoting objects which we may have in common.

"Either by transferring a portion of the land around the Exhibition building, by assisting your Society to erect upon it a building adapted for its uses, or by securing your co-operation in the extension of the present building upon a plan adapted to your wants, we hope that this Board may be of assistance to you, and receive co-operation and support in return.."

Your Council would recommend the consideration of this matter to the Society, in furtherance of the said object.

Your Council cannot but express its regret, that the report of the treasurer shows a balance against the Society; and would urge, that efforts be made by each individual member, to endeavor by all means to increase the funds so necessary for the support and furtherance of the objects for which it was founded.

Your Council must now resign their charge into the hands of others, wishing them a prosperous and increasing year of usefulness. One thing your Council would place on record, is the kindness and unanimity that has actuated the whole of the members, a sure prestige of increasing strength and usefulness; and they close their report with a fervent hope, that the Montreal Natural History Society may grow and prosper.

MONTHLY MEETING.

The monthly meeting of the Society took place at its rooms, on Monday evening, May 30th, Dr. Dawson, President, in the chair. The following donations were announced:

To the Museum.

From A. Ramsay, Esq.—Fine specimen of the Snow Goose (*Anser hyperboreus*, Pallas), shot at Nun's Island.

From James Ferrier, jun., Esq.—The Turnstone *Strepsilas interpres*, Illiger ; Curious Japanese Mirror and Case.

From Mrs. McCulloch.—138 skins of Canadian birds, 5 do foreign, 20 do. mammals.

From E. E. Shelton, Esq.—4 Indian pipes, from an excavation in Hospital Street.

From Jas. Claxton, Esq.—8 specimens of minerals (Quartz, Quartz with Pyrites, Calc Spar, and Sulphate of Barytes,, from Devon and Cornwall, England.

From Mr. W. Hunter.—The yellow-bellied Woodpecker (*Centurus flaviventris*, Swainson); the golden-winged Woodpecker (*Colaptes auratus*, Linn.); 2 Robins (*Turdus migratorius*, Linn.); 1 blue yellow-backed Warbler (*Parula Americana*, Bonaparte).

To the Library.

Preliminary List of the Plants of Buffalo.—From the Buffalo Society of Natural Sciences.

Arboretum et Fruticetum Britannicum, by J. C. Loudon; 8 vols. 8vo., illustrated. From James Ferrier, jun., Esq.

Bombay Magnetical and Meteorological Observations, 1862.

New Members.

John Tempest, and Alexander S. Ritchie, Esqs., were elected ordinary members of the Society.

Proceedings.

The Recording Secretary then read a communication by Dr. Bowerbank, on two new N. American Sponges. The first of these was a small marine form (of the genus *Tethea*), dredged by Dr. Dawson off the coast of Portland, Maine. The second was a green fresh-water species (of the genus *Spongilla*), occurring in quiet little bays along the St. Lawrence about Montreal, also in Upper Canada, in which places it has been taken by Dr. Dawson, Rev. A. F. Kemp, Mr. R. J. Fowler, and others. Dr. Dawson remarked that a great number of the N. American sponges differed somewhat from allied European forms, and were probably new species. The present paper, he remarked, might be looked upon as the first instalment of a somewhat elaborate memoir upon these very ill-understood and low forms of animal life, to the study of which Dr. Bowerbank has paid much attention. Dr. Dawson then gave an account of several species of Annelida and Bryozoa, from Mingan and Metis. The Mingan specimens were collected by Mr. Richardson, jun., of the Geol. Survey, and the Metis forms by Mrs. H. Parkinson. The doctor commenced by making drawings explanatory of the structure of the animal of the genus Spirorbis. He explained that these creatures were marine worm-like animals, which constructed small, flattened spiral shells, which were generally attached to sea-weeds, stones, or shells. He then exhibited eight different species of this genus, and pointed out lucidly the difference between them. After exhibiting a species of Serpula, with its irregular cylindrical shelly tube, the Doctor called attention to some of the Bryozoa of the Gulf. He stated that some of the species resembled brown sea-weeds, others corallines, but that the structure of the animals was nearest to that of some of the bivalve shells. He exhibited examples of some fifteen or sixteen species, illustrating the subject by diagrams, and by microscopical preparations showing the shape of the cells of these creatures, and some of their organs of defence. After some discussion as to the supposed uses of these animals, the meeting broke up.

On the Bivalved Entomostraca of the Carboniferous Strata of Great Britain and Ireland.

By Professor T. Rupert Jones, F G.S., and J. W. Kirby, Esq.

After a review of what former observers have published on the Bivalved Entomostraca of the Carboniferous formations, the authors proceed to point out: 1st, a few rather doubtful *Cyprides* or *Candonæ*, from the Coal-measures. 2ndly, *Cytheres;* of which there are about eight species, chiefly from the Coal-measures. 3rdly, *Bairdiæ;* about eight species, mostly from the Mountain-limestone and its shales. 4thly, *Cypridinidnæ;* comprising *Cypridina*, *Cypridella*, *Cyprella*, *Entomoconchus*, and *Cytherella*, from the Mountain-limestone. A fine collection of these rare forms from Little Island, Cork, liberally placed at Messrs. Jones and Kirkby's disposal by Mr. Joseph Wright, will elucidate the relationships of these hitherto obscure genera and their species. 5thly, *Leperditidæ;* comprising *Leperditia* (to which genus belong the so-called *Cypris Scotoburdigalensis*, *C. inflata*, *C. subrecta*, *Cythere inornata*, and others; many of them dwarf varieties of one species, and mostly belonging to the Mountain-limestone series); *Entomis* (Mountain-limestone), Devonian and Carboniferous forms of which have been mistaken for *Cypridinidnæ;* *Beyrichiæ* (from nearly all parts of the Carboniferous system, several species, of which *B. arcuata*, Bean, sp., is the most common); and *Kirkbyæ*, somewhat rare, and chiefly from the Mountain-limestone series.

Leperditia and *Beyrichia* are also Silurian and Devonian genera; they do not appear to pass upwards into the Permian formation. *Bairdia* and *Kirkbya* occur first in the Carboniferous and re-appear in the Permian deposits, even in the same specific, forms; and *Bairdia* has been freely represented in Secondary and Tertiary deposits, and exists at present. Of the *Cypridinidæ* under notice, *Cypridella, Cyprella*, and *Entomoconchus* appear to be confined to the Mountain-limestone; *Cypridina* occurs in the Permian, and with *Cytherella* is found in Secondary and Tertiary rocks, and in existing seas. *Entomis* is a Silurian and Devonian genus, especially characterizing the so-called "Cypridinen-Schiefer" of Germany.

M'Coy's *Daphna primæva* is a *Cypridina*; De Koninck's *Cypridina Edwardsiana* and *Cypridella cruciata* are *Cypridellæ*: his *Cypridina annulata* and *Cyprella chrysalidea* are *Cyprellæ*; and his *Cypridina concentrica* is an *Entomis*.

MISCELLANEOUS.

THE LATE PRINCIPAL LEITCH.

Our issue of yesterday contained the sad, though not unexpected, announcement of Principal Leitch's death. William Leitch was born at Rothsay, in the Island of Bute, Scotland, in the year 1814, and was at his death under fifty years of age. The robust health of his boyhood was taken from him by an accident, which confined him for eighteen months, and threatened even his life before he recovered. When about fourteen years of age he fell from the mast of a yacht in the bay of his native town, and the fall produced a comminuted fracture of the hip-joint, which made him lame for life. This accident was the occasion of determining, in a somewhat remarkable way, the tendencies by which all his subsequent life has been characterized; for during his long and dreary confinement, the relief from intense suffering, which most boys of even high intellectual character would have sought in the fascination of fiction, he found in the study of mathematics; and his after life, which became almost from necessity that of a student, was devoted chiefly to the mathematical sciences. After finishing his preparatory studies for the Church of Scotland, he did not immediately enter on the practical work of his profession, but remained for some years in connection with the Glasgow Observatory, under the late Professor Nichol. In the year 1843 however, he accepted a presentation to the Parish of Monimail in Fifeshire, where he found that congenial quiet in which he was able to continue his studies and to extend his inquiries into other branches of physical science, as well as into those departments of philosophy and theology with which the physical sciences are more closely connected. During his residence at Monimail, he made himself known by extensive contributions to various periodicals and cyclopedias, on those subjects to which he had specially devoted his time; and by this means he enjoyed an intimate acquaintance with many of the most distinguished literary scientific men in Great Britain. The science to which he remained most fondly attached was that of astronomy; and from his thorough familiarity with the practical work of an Observatory, from the enthusiasm with which he studied every improvement in astronomical instruments, and hailed every fresh discovery to which it led, as well as from his general scientific attainments, it was thought probable that, had he not left Scotland, he would have been appointed to the chair of his teacher, the late Professor Nichol, in the University of Glasgow. De Quincey, in a noble article on Lord Rosse's telescope, speaks of his friend Professor Nichol as having contributed more than any other living man to keep general English readers, who have not time for the scientific investigations of astronomers, acquainted with the latest and profoundest results to which these investigations are leading; and during the two years which have passed since the Professor's death, it would be difficult to point to a man for whom the same distinction could have been so justly claimed as the late Principal of our University.

In 1860 he was invited by the Trustees of the Queen's University to become its Principal; and after spending session 1860-61 in the duties of the office, he decided to accept their invitation. His brief and sad career among us is so unfinished that even its imperfect results, and certainly, at least the larger and nobler aims by which it was guided, could be adequately described only at greater length than is possible in a hurried newspaper notice. Those who have been interested in his movements must have recognized the hopes which he entertained for the progress of science by the efficient working of our Observatory, and for the advancement of higher education by a more orderly government of our University, as well as by a reform in the general relations of all the Universities of Upper Canada.—*Kingston News, May 11th.*

Published, Montreal, June 15, 1864.

ABSTRACT OF METEOROLOGICAL OBSERVATIONS,

Taken at the Montreal Observatory, Latitude 45° 31′ N. Longitude, 4h. 54m. 11s. W. of Greenwich. Height above level of the Sea 182 feet. For the month of January 1864.

BY CHARLES SMALLWOOD, M.D., LL.D.

Day of Month.	Reading of the Barometer, corrected, and reduced to 32° F.			Reading of Thermometer.			Mean Tension of Vapor.	Mean Humidity of the Atmosphere.	General direction of Wind.	Horizontal movement in 24 hours in miles.	Mean extent of Clouds in 10ths.	Depth of Rain in inches.	Depth of Snow in inches.	Ozone in 10ths.	Weather, &c.
	Highest	Lowest.	Mean.	Max.	Min.	Mean									
	Inches.	Inches.	Inches.												
1	29.183	29.414	29.242	35.0	18.4	27.2	.160	.898	S W	87.82	6.3	Inapp	....	2.6	Rain.
2	.900	.636	.766	8.0	-9.1	0.5	.044	.843	W	440.40	2.0	Inapp	....	1.3	Rain.
3	.898	.859	.872	18.9	-2.0	11.7	.079	.846	S W	455.90	1.3	....	Inapp	2.0	Snow.
4	30.100	.888	30.019	19.4	0.0	10.6	.076	.846	S W	200.00	1.6	....	....	1.6	Aurora Bor.
5	29.884	.700	29.772	10.0	-2.0	6.7	.067	.871	N E	34.40	6.6	....	2.20	2.6	Snow.
6	30.149	.893	30.074	6.2	0.0	5.4	.057	.895	S W	72.10	6.3	....	Inapp	2.0	Snow.
7	.830	30.110	.237	9.6	-16.9	-0.8	.044	.863	W	57.66	2.6	....	....	1.3	
8	29.800	29.790	29.844	24.2	5.0	15.7	.192	.883	S W	24.70	10.0	....	....	2.6	
9	.760	.541	.640	23.7	11.4	17.5	.100	.844	S W	56.52	6.6	....	Inapp	3.0	Snow.
10	.614	.600	.605	25.3	18.9	23.2	.127	.877	S W	299.44	10.0	....	....	2.6	
11	.604	.499	.554	27.1	18.1	23.2	.146	.889	S W	104.06	6.6	....	1.20	2.6	Snow.
12	.648	.462	.559	29.6	16.4	24.4	.157	.902	N E	60.90	10.0	....	....	3.0	
13	.600	.433	.511	37.8	29.4	34.1	.205	.944	S W	77.30	10.0	....	....	3.0	
14	.900	.681	.801	34.9	23.2	27.6	.152	.869	S W	84.50	4.0	....	....	6.6	
15	.709	.572	.627	36.6	18.1	26.6	.147	.889	N E	96.50	10.0	....	3.20	4.6	Snow.
16	30.098	.837	.977	25.2	4.0	15.4	.086	.837	W	180.57	4.0	....	0.20	1.3	Snow.
17	.040	.971	30.037	32.2	21.0	28.3	.165	.920	S W	54.00	4.6	....	....	2.6	
18	29.993	.962	29.975	37.8	27.4	34.4	.188	.912	S W	202.80	10.0	....	3.10	4.0	Snow.
19	.876	.211	.520	26.7	24.0	25.9	.151	.936	N E	38.20	10.0	....	4.10	5.0	Snow.
20	30.094	.519	.791	23.0	18.1	22.1	.119	.849	W	239.12	9.3	....	2.05	2.6	Snow.
21	.255	30.200	30.234	32.2	3.8	16.6	.105	.860	W	174.38	0.0	....	....	2.3	
22	29.875	29.855	29.864	34.1	17.4	28.8	.169	.929	S W	45.19	6.6	Inapp	Inapp	2.6	Snow. Rain.
23	.845	.525	.723	35.2	21.2	30.9	.178	.919	W S W	124.10	7.6	Inapp	1.10	3.3	Snow.
24	.482	.298	.383	40.1	30.1	33.7	.231	.924	S W	28.14	10.0	0.100	....	4.6	Rain.
25	.533	.329	.424	47.1	30.1	36.8	.217	.902	W	58.13	6.6	....	....	2.6	
26	.781	.325	.602	38.7	17.3	27.7	.153	.867	N E	112.72	3.3	....	5.60	3.3	Snow.
27	.877	.568	.728	28.1	15.0	23.6	.131	.882	N E	146.04	10.0	....	Inapp	3.0	Snow.
28	.924	.829	.904	42.0	22.1	33.3	.180	.838	S W	91.68	10.0	....	....	3.0	
29	30.300	30.177	30.253	25.1	15.8	19.8	.198	.794	N E	115.48	7.0	....	....	2.6	
30	.314	.150	.221	19.0	11.5	16.3	.091	.811	N E	146.70	10.0	....	3.19	4.0	Snow.
31	.234	.148	.247	24.1	18.9	20.2	.106	.820	N E	243.80	6.6	....	2.00	2.6	Snow.

Remarks for the Month.

Barometer.... { Highest, the 30th day, 30.314 inches. Lowest, the 19th day, 29.211 " Monthly Mean, 29.937 " Monthly Range, 1.103 " }

Thermometer { Highest, the 25th day, 47°1. Lowest, the 7th day, −16°9. Monthly Mean, 21°52. Monthly Range, 64°0. }

Greatest intensity of the Sun's rays, 64°7.
Lowest point of Terrestrial radiation, −18°4.
Mean of Humidity, .857.
Rain fell on 5 days, amounting to 0.100 inches.
Snow fell on 16 days, amounting to 32.85 inches.
Most prevalent wind, S. W.
Least prevalent wind, W.
Most windy day the 3rd day, mean miles per hour, 20.24.
Least windy day the 8th day, mean miles per hour, 1.02.
Aurora Borealis visible 1 night.
Zodiacal light, bright.
Imperfect Solar Halo, 20th day.

ABSTRACT OF METEOROLOGICAL OBSERVATIONS,

Taken at the Montreal Observatory, Latitude 45° 31′ N. Longitude, 4h. 54m. 11s. W. of Greenwich. Height above the level of the Sea 182 feet. For the month of February 1864.

BY CHARLES SMALLWOOD, M.D., LL.D.

Day of Month.	Reading of the Barometer, corrected, and reduced to 32° F.			Reading of Thermometer.			Mean Tension of Vapor.	Mean Humidity of the Atmosphere.	General direction of Wind.	Horizontal movement in 24 hours in miles	Mean extent of Clouds in 10ths.	Depth of Rain in inches.	Depth of Snow in inches.	Ozone in 10ths.	Weather, &c.
	Highest	Lowest.	Mean.	Max.	Min.	Mean									
	Inches.	Inches.	Inches.												
1	29.986	29.643	29.809	26.1	2.5	24.2	.133	.893	S W	454.00	10.0	....	13.6	5.0	Snow.
2	.650	.450	.607	39.8	20.0	34.7	.199	.911	S W	423.60	10.0	Inapp	0.3	5.0	Snow.
3	.511	.424	.472	40.0	29.2	32.3	.178	.832	N E by E	23.80	10.0	Inapp	0.50	4.0	Rain—Snow.
4	.581	.495	.525	38.4	20.4	30.7	.165	.883	N E by E	46.36	8.0	Inapp	Inapp	5.0	Rain—Snow.
5	.632	.431	.535	36.8	4.2	33.8	.186	.892	S W	102.97	10.0	0.30	Inapp	4.3	Rain—Snow.
6	.690	.678	.681	37.2	25.2	33.1	.175	.834	W S W	37.77	9.3	....	0.30	2.0	Snow.
7	.571	.430	.477	35.4	23.0	32.2	.176	.887	S W	300.59	10.0	....	....	4.0	
8	.472	.201	.318	43.2	26.0	34.6	.169	.854	S W	588.00	6.6	....	0.40	3.8	Snow.
9	.816	.604	.739	27.0	7.4	16.6	.098	.847	W	175.59	1.3	....	0.40	2.0	Snow.
10	30.156	.924	30.028	15.3	-8.9	3.0	.055	.844	N W	112.20	1.3	..	....	1.0	
11	.146	.570	29.886	22.0	-4.7	12.2	.037	.851	S W	221.41	7.6	....	1.00	3.3	Snow.
12	29.581	.478	.622	41.1	18.4	28.6	.162	.879	W	190.99	4.0	....	2.40	3.6	Snow.
13	.489	.354	.414	34.8	25.1	33.4	.184	.877	S W	164.37	10.0	....	Inapp	3.0	Snow.
14	.728	.875	.601	27.9	14.0	22.0	.132	.885	N E	195.24	6.6	....	....	3.6	
15	30.010	.550	.823	7.1	-10.1	0.5	.065	.899	N	145.24	4.6	....	5.25	2.6	Snow.
16	29.262	.078	.164	20.0	6.8	14.2	.089	.884	N E	81.56	8.6	....	4.10	2.6	Snow.
17	.901	.824	.377	-6.3	-19.4	-12.5	.033	.824	W	128.50	5.3	....	0.50	2.0	Snow.
18	30.221	30.161	30.194	18.9	-20.4	-3.1	.042	.809	W S W	168.96	6.0	....	....	2.0	
19	.256	.025	.161	22.0	-12.0	8.1	.078	.824	W by S	73.43	2.6	....	....	2.6	
20	29.971	29.891	29.947	37.3	10.0	24.4	.138	.876	W by S	156.60	6.0	....	Inapp	2.6	Snow.
21	.900	.398	.900	37.4	29.2	33.1	.178	.862	W by S	108.00	8.6	....	...	2.3	
22	.861	.459	.690	40.8	29.2	35.8	.207	.880	S W	152.91	10.0	Inapp	....	3.6	Rain.
23	.600	.472	.525	48.9	33.1	41.3	.239	.858	W S W	277.96	6.0	0.390	....	3.3	Rain.
24	.500	.314	.432	58.2	31.6	45.5	.201	.874	S W	100.28	8.0	....	....	3.3	
25	.731	.626	.693	42.2	28.4	32.6	.174	.845	N by [illegible]	66.79	3.6	....	....	2.3	
26	.762	.711	.748	35.1	14.5	28.3	.151	.847	N N W	207.39	2.0	...	....	2.3	
27	.882	.863	.873	42.3	11.2	25.7	.143	.850	W	125.47	0.0	..	....	2.0	
28	.642	.599	.624	38.9	33.4	37.1	.196	.809	S W	234.33	10.0	....	....	2.6	
29	.998	.599	.826	40.2	26.4	31.5	.167	.897	S W	95.82	8.3	0.110	....	2.6	Rain.

Remarks for the Month.

Barometer.... { Highest, the 19th day, 30.256 inches.
Lowest, the 16th day, 29.078 "
Monthly Mean, 29.929 "
Monthly Range, 1.178 "

Thermometer { Highest, the 24th day, 58.2°.
Lowest, the 18th day, -20.4°.
Monthly Mean, 25.32°.
Monthly Range, 78.6°.

Greatest intensity of the Sun's rays, 74.0°.
Lowest point of Terrestrial radiation, -22.7°.
Mean Humidity .865.
Rain fell on 7 days, amounting to 0.790 inches.
Snow fell on 15 days, amounting to 28.75 inches.
Most prevalent wind, S. W.
Least prevalent wind, N. W.
Most windy day the 8th day, mean miles per hour, 24.50.
Least windy day the 3rd day, mean miles per hour, 1.40.
Zodiacal light, bright.