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THE
CANADIAN NATURALIST.

SECOND SERIES.

CONTRIBUTIONS TO THE CHEMISTRY OF
NATURAL WATERS.

By T. STERRY HUNT, A.M., F.R.S.; of the Geol. Survey of Canada.

II.

ANALYSES OF VARIOUS NATURAL WATERS.

CONTENTS OF SECTIONS.—35, mode of analysis, date of collection; 37, waters of the first class; 37, their probable origin; the elimination of sulphates; 38, separation of lime-salts from waters; 39, earthy chlorids in saliferous formations; brines of New York, Michigan, and England; foot-note on errors in water-analyses; 40, brines of western Pennsylvania; waters in which chlorid of calcium predominates; 41, origin of such waters; separation of magnesia as an insoluble silicate; 42, waters of the second class; 43, waters of the third class; 44, waters of the fourth class; Chambly; 45, other waters of the same class; Ottawa River; 46, waters of Highgate and Alburg; 47, changes in the Caledonia waters; comparative analyses; 48, waters of the fifth class; sulphuric-acid springs of New York and Canada; 49, changes in the composition of these waters; their action on calcareous strata; 50, waters of the sixth class, their various sources; 51, examples of neutral sulphated waters; sulphate of magnesia waters.

§ 35. The analyses of the various mineral waters to be given in the second part of the present paper, were made according to the modes laid down in the treatise of Fresenius on Quantitative Analysis. The carbonate of soda in the alkaline waters was determined by the excess of the alkaline bases over the chlorine and sulphuric acid present. This was generally controlled by the amount of the carbonate of baryta thrown down from a solution of chlorid of barium by a solution of the soluble salts obtained by the evaporation of the mineral water; and in some cases, to be specified farther on, this latter process was relied on as the only means

of determining the amount of carbonate of soda. For some remarks on the earthy carbonates of the waters, and on their relation to the results of analysis, see part III of this paper.

The date at which the various waters were collected for analysis is in each case appended to the notice of the spring. This is of the greater importance, inasmuch as it will be shown that in the course of years, some of those springs here described have suffered considerable changes in their composition.

§ 36. In the following table are given the analyses of several waters belonging to the first class, as defined in § 34.*

1.—This water is from a well thirty feet in depth, near the village of Ancaster, on the western shore of Lake Ontario. It is sunk in the Niagara formation; but like the other waters of this class, probably has its source in the Lower Silurian limestones. The water rises nearly to the surface, but there is no perceptible discharge. Its temperature was found to be 48° F. when collected for analysis in September 1847.

2. This water is from a copious spring which issues from the limestones of the Trenton group at Whitby, on the north shore of Lake Ontario. It contained small portions of baryta and strontia, and was collected in October 1853.

3, 4. Several wells have been sunk in the Trenton limestone in the township of Hallowell, on the Bay of Quinté, Lake Ontario, in search of brine for salt-making, and have yielded bitter saline waters, of which the two here noticed are examples. No. 3 was obtained from a well twenty-seven feet deep, in October 1853. No. 4 was taken in the summer of 1854 from a well a mile or two distant from the last. Neither of these waters was examined for baryta or strontia.

5, 6. At St. Catharines, near Niagara Falls, a boring of five inches in diameter was carried to a depth of about 500 feet, and after traversing the Medina formation, is said to have penetrated fifty or sixty feet into the Hudson River shales. It yields about twenty gallons a minute of a saline water, whose analysis by Professor Croft of the University of Toronto, a few years since, afforded the results given under 5. This water, which was

* Of the thirty-seven analyses of waters here given, ten have already appeared in Silliman's *Journal* [2] viii, ix, xi, but for the purposes of comparison it is thought well to reproduce them in the present connection. Of the others, the greater part have appeared in the *Geology of Canada*, but several are now for the first time in print.

TABLE I.—WATERS OF THE FIRST CLASS.

	1	2	3	4	5	6	7	8
Chlorid of sodium	17.8280	18.9158	38.7315	17.4000	29.8034	19.94	29.864	7.227
“ potassium .....	.0920	traces	traces	undet.	.3555	undet.	undet.	undet.
“ calcium	12.8027	17.5315	15.9230	9.2050	14.8544	6.49	12.439	2.102
“ magnesium	5.0737	9.5437	12.9060	9.4843	3.3977	1.95	7.33	1.703
Bromid of sodium .....	.1178	.2482	.4685	undet.	undet.	undet.	undet.	undet.
Iodid of “ .....	.....	.0063	.0133	“	.0042	.....	“	“
Sulphate of lime .....	.7767	.....	.....	.....	2.1923	1.77	.954	2.388
Carbonate of lime	traces	.0411	.....	.....	.....	.....	.370	.400
“ magnesium .....	.....	.0227	.....	.....	.....	.....	1.287	.....
“ baryta and strontia .....	.....	undet.	.....	.....	.....	.....	.....	.....
In 1000 parts	36.6911	46.3038	68.0423	36.0893	50.6075	30.15	52.251	13.829

first sought for the manufacture of salt, is now much used for medicinal purposes. Its strength seems subject to some variation, since a specimen from the same well in December 1861 gave me, by a partial analysis, chlorid of sodium 23.00, chlorid of calcium 9.66, chlorid of magnesium 2.40, sulphate of lime 1.75; = 36.81 parts in 1000. No. 6, examined at the same time, is from a second well sunk in 1861, not far from the last.

7, 8.—These are analyses of the waters from two borings in the Trenton limestone at Morton's distillery in Kingston. The analyses are by Dr. Williamson of Queen's College in that city, and were made probably ten or twelve years since. They have been recalculated so as to represent the whole of the sulphuric acid as combined with calcium. The first of these waters gave to Dr. Williamson both bromine and iodine, and the second was found to be sulphurous. These waters differ from the preceding in containing considerable amounts of earthy carbonates, and in this respect are related to those of the second class, while they still show a large predominance of earthy chlorids.

§ 37. The waters of the above table contain, besides chlorid of sodium and a little chlorid of potassium, large quantities of the chlorids of calcium and magnesium, amounting together, in several cases, to more than one half the solid contents of the water. Sulphates are either absent, or occur only in small quantities, and the same is true of earthy carbonates. Salts of baryta and strontia are sometimes present, while the proportions of bromids and iodids, though variable, are often considerable.

In the large amount of magnesian chlorid which they contain, these waters resemble the bittern or mother-liquor which remains after the greater part of the chlorid of sodium has been removed from sea-water by evaporation. The bitterns from modern seas, however differ in the presence of sulphates, and in containing, when sufficiently concentrated, only traces of lime. The reason of this, as already pointed out in § 22, is to be found in the fact that in the waters of the present ocean the sulphates are much more than equivalent to the lime, so that this base separates during evaporation as gypsum.* But as shown in § 23 and § 24, the waters of the ancient seas, which held in the form of chlorid of calcium the greater part of the lime since deposited as carbonate, must have yielded by evaporation bitterns containing a large proportion of chlorid of calcium. Such is the nature of the

* See farther on this point, Bischof, Chem. Geology, i, 413.

brines whose analyses are given in the above table, and such we suppose to have been their origin. The complete absence of sulphates from many of these waters points to the separation of large quantities of earthy sulphates in the Lower Silurian strata from which these saline springs issue; and the presence in many of the dolomitic beds of the Calciferous sand-rock of abundantly disseminated small masses of gypsum, is an evidence of the elimination of the sulphates by evaporation. The frequent occurrence of crystalline masses of sulphate of strontian in the Chazy and Black River limestones of this region, is also to be noted as another means by which the sulphates were separated from the waters of the Lower Silurian seas. From the proportions of chlorid of sodium, varying from about one third to more than two thirds of the solid contents of the above waters, it is apparent that in most cases the process of evaporation had gone so far as to separate a part of the common salt; and thus successive strata of this ancient saliferous formation must be impregnated with solid or dissolved salts of unlike composition. The mingling of these in varying proportions affords the only apparent explanation of the differences in the relative amounts of the several chlorids in waters from the same region, and even from adjacent sources. These differences are seen on comparing the waters from the different wells of St. Catherines, Hallowell and Kingston, with each other.

§ 38. The great solubility of chlorid of calcium renders it difficult to suppose its separation from the mother-liquors so as to be deposited in a solid state in the strata. The same remark applies to chlorid of magnesium. It is however to be remarked that the double chlorid of potassium and magnesium (carnallite) is decomposed by deliquescence into solid chlorid of potassium and a solution of chlorid of magnesium; and thus strata like those which at Stassfurth contain large quantities of carnallite (§ 22), might give rise to solutions of magnesian chlorid. This however would require the presence of a large amount of chlorid of potassium in the early seas. It will be observed by referring to the analyses above given, that the chlorid of magnesium sometimes surpasses in amount the chlorid of calcium; and sometimes, on the contrary, is equal to only one half or one fourth of the latter salt. While it is not impossible that the predominance of the magnesian chlorid in some waters may be traced to the decomposition of carnallite, it is undoubtedly in most cases connected with the action of solutions of carbonate of soda; the effect of which, as already pointed out, is to first

separate the soluble lime-salt as carbonate, leaving to a subsequent stage the magnesian chlorid (§ 18.) As this reaction replaces the calcium-salt by chlorid of sodium, it might be expected that there would be an increase in the amount of the latter salt in the water wherever the magnesian chlorid predominates, did we not remember that evaporation separates it from the water in a solid form; and that the two processes, one of which replaces the chlorid of calcium by chlorid of sodium, while the other eliminates the latter salt from the solution, might have been going on simultaneously or alternately. As the nature of the waters now under consideration shows that the process of evaporation had been carried so far as to separate the sulphate in the form of gypsum, and probably also a portion of the chlorid of sodium in a solid state, it is evident that we have not yet the data necessary for determining the composition of the water of the Lower Silurian ocean, as regards the proportions of the sodium, calcium, and magnesium which it held in solution; and we can only conclude from these mother-liquors, that the amount of the earthy bases was relatively very large.

§ 39. As already remarked in § 22, the mother-liquor from modern sea-water contains no chlorid of calcium, but, on the contrary, large quantities of sulphate of magnesia; the lime in the modern ocean being less than one-half that required to combine with the sulphate present. If however we examine the numerous analyses of rock-salt and of brines from various saliferous formations, we shall find that chlorid of calcium is very frequently present in both of them; thus supporting the conclusions already announced in § 24 with regard to the composition of the seas of former geological periods. The oldest saliferous formation which has been hitherto investigated is the Onondaga Salt-group of the New York geologists, which belongs to the upper part of the Silurian series, and supplies the almost saturated brines of Syracuse and Salina in New York. These, notwithstanding their great purity, contain small proportions of chlorids of calcium and magnesium, as shown by the analyses of Beck, and the recent and careful examinations of Goessmann. In the brines of that region the solid matters are equal to from 14.3 to 16.7 per cent., and contain on an average, according to the latter chemist, 1.54 of sulphate of lime, 0.93 of chlorid of calcium, and 0.88 of chlorid of magnesium in 100.00; the remainder being chlorid of sodium.*

* Goessmann. Report on the Brines of Onondaga: Syracuse, 1862 and 1864. Also Report on the Onondaga Salt Co.: Syracuse, 1862.

The nearly saturated brines from the Saginaw valley in Michigan, which have their source at the base of the Carboniferous series, contain, according to my calculation from an analysis by Prof. Dubois, in 100.00 parts of solid matters: chlorid of calcium 9.81, chlorid of magnesium 7.61, sulphate of lime 2.20, the remainder being chiefly chlorid of sodium. Another brine in the same vicinity gave to Chilton an amount of chlorid of calcium equal to 3.76 per cent.* In a specimen of salt manufactured in this region, Goessmann found 1.09 of chlorid of calcium; and in two specimens of Ohio salt, 0.61 and 1.43 per cent of the same chlorid. The rock-salt from the Lias of Cheshire, according to Nicol, contains small cavities, partly filled with air, and partly with a concentrated solution of chlorid of magnesium, with some chlorid of calcium.†

* Winchell; Silliman's Journal [2] xxxiv, 311.

† Cited by Bischof, Lehrbuch, ii, 1671. The results of the analyses by Mr. Northcote of the brines of Droitwich and Stoke in the same region (L. E. & D. Philos. Mag. [4] ix, 22), as calculated by him, show no earthy chlorids whatever, and no carbonate of lime, but carbonates of soda and magnesia, and sulphates of soda and lime. He regarded the whole of the lime present in the water as being in the form of sulphate. If however we replace in calculating these analyses, the carbonate of soda and sulphate of lime by sulphate of soda and carbonate of lime, we shall have for the contents of these brines, chlorid of sodium, with notable quantities of sulphate of soda, some sulphate of lime, and carbonates both of lime and magnesia; a composition which is more in accordance with the admitted laws of chemical combinations. From these results, it would appear that the earthy chlorids, which according to Nichol are present in the rock-salt of this formation, are decomposed by sulphates in the waters which, by dissolving it, give rise to the brines.

It is to be regretted that in many water-analyses by chemists of note, the results are so calculated as to represent the co-existence of incompatible salts. Of the association of carbonates of soda and magnesia with sulphate of lime, as in the analysis just noted, it might be said that I have shown that it may occur in the presence of an excess of carbonic acid. (Silliman's Jour. [2] xxviii, 174). By evaporation, however, such solutions regenerate carbonate of lime and sulphates of soda and magnesia; and by the consent of the best chemists these elements are to be represented as thus combined. But what shall be said when chlorid of magnesium, carbonate of soda, and silicate of soda are given as the constituents of a water whose recent analysis may be found in a late number of the *Chemical News*; or when bi-carbonates of soda, magnesia, and lime are represented as co-existing in a water with sulphates and chlorids of magnesium and aluminum? These errors probably arise from

§ 40. The brines from the valley of the Alleghany River, obtained from borings in the Coal formation, are remarkable for containing large proportions of chlorids of calcium and magnesium; though the sum of these, according to the analyses of Lenny, is never equal to more than about one fourth of the chlorid of sodium. The presence of salts of barium and strontium in these brines, and the consequent absence of sulphates, is, according to Lenny, a constant character in this region over an area of two thousand square miles. (See Bischof, Chem. Geol., i, 377.) A later analysis of another one of these waters from the same region, by Steiner, is cited by Will and Kopp, Jahresbericht, 1861, p. 1112. His results agree closely with those of Lenny. See also the analysis of a bittern from this region by Boyé (Silliman's Journal [2] vii, 74).

These remarkable waters approach in character to those of Whitby and Hallowell; but in these the chlorid of sodium forms only about one half the solid contents, and the proportion of the chlorid of magnesium to the chlorid of calcium is relatively much greater than in the waters from western Pennsylvania, where the magnesian chlorid is equal only to from one third to one fifth of the chlorid of calcium; the proportions of the two being subject in both regions to considerable variations.

In this connection may be cited a water from Bras d'Or, in the island of Cape Breton, lately analyzed by Prof. How, which contains in 1000 parts, chlorid of sodium 4.901, chlorid of potassium 0.650, chlorid of calcium 4.413, and chlorid of magnesium only 0.638, besides sulphate of lime 0.134, carbonates of lime and magnesia 0.085, with traces of iron-oxyd and phosphates; = 10.821. (Canadian Naturalist, viii, 370.) The analyses of European waters furnish comparatively few examples of the predominance of earthy chlorids.*

determining in the recent water, or in water not sufficiently boiled, the lime and magnesia which would by prolonged ebullition be separated as carbonates, together with portions of alumina, silica, etc. In the subsequent calculation of the analyses, these dissolved earthy bases being regarded as sulphates or chlorids, instead of carbonates, there remains an excess of soda, which is wrongly represented as carbonate, instead of chlorid, or sulphate of sodium.

* Lersch, Hydro-Chemie, Zweite Auflage: Berlin, 1864; *vide* p. 207. This excellent work, which is a treatise on the chemistry of natural waters, in one volume 8vo. of 700 pages, was unknown to me when I prepared the first part of this essay.

§ 41. We have already shown in § 38 how the action of carbonate of soda upon sea-water or bittern will destroy the normal proportion between the two chlorids of magnesium and calcium by converting the latter into an insoluble carbonate, and leaving at last only salts of sodium and magnesium in solution. A process the reverse of this has evidently intervened for the production of waters like that from Cape Breton, and some others noticed by Lersch, in which chlorid of calcium abounds, with little or no sulphate or chlorid of magnesium. This process is probably one connected with the formation of a silicate of magnesia. Bischof has already insisted upon the sparing solubility of this silicate; and he observed that silicates of alumina, both artificial and natural, when digested with a solution of magnesian chlorid, exchange a portion of their base for magnesia, thus giving rise to solutions of alumina; which, being decomposed by carbonates, may have been the source of many of the aluminous deposits referred to in § 9. He also observed a similar decomposition between a solution of an artificial silicate of lime and soluble magnesian salts. (Bischof, Chem. Geology, i, 13, also chap. xxiv.) In repeating and extending his experiments, I have confirmed his observation that a solution of silicate of lime precipitates silicate of magnesia from the sulphate and the chlorid of magnesium; and have moreover found that by digestion at ordinary temperatures with an excess of freshly precipitated silicate of lime, chlorid of magnesium is completely decomposed; an insoluble silicate of magnesia being formed, while nothing but chlorid of calcium remains in solution. It is clear that the greater insolubility of the magnesian silicate, as compared with silicate of lime, determines a result the very reverse of that produced by carbonates with solutions of the two earthy bases. In the one case the lime is separated as carbonate, the magnesia remaining in solution; while in the other by the action of silicate of soda (or of lime), the magnesia is removed and the lime remains. Hence carbonate of lime and silicate of magnesia are everywhere found in nature; while carbonate of magnesia and silicate of lime are produced only under local and exceptional conditions. The detailed results of some experiments on this subject are reserved for another place. It is evident that the production from the waters of the early seas of beds of sepiolite, tale, serpentine, and other rocks in which a magnesian silicate abounds, must, in closed basins, have given rise to waters in which chlorid of calcium would predominate.

§ 42. Of the waters of the second class whose analyses are here given, the first three occur, with many others of similar character, on the south side of the Ottawa river, below the city of that name. The remaining four are on the north side of the St. Lawrence, between Montreal and Quebec, where also similar waters abound. All of these springs rise from the Lower Silurian limestones of the region.

1, 2. These two waters are from the township of Plantagenet. The first is known as Larocque's, and the second as the Georgian spring. These waters were examined in 1849 and 1851. Two other springs have been observed in the same vicinity, one resembling Larocque's spring and containing borates, with a notable proportion of strontia, while the other is an alkaline-saline water of the third class.

3. Caledonia Intermittent Spring. This spring owes its name to the intermitting discharge of carburetted hydrogen which takes place from its waters. It is in the township of Caledonia, not far from Plantagenet, and near three other waters from the same township, to be mentioned in the next class. The water was collected in September 1847.

4. Lanoraie. This is from the seigniorie of Lanoraie. It contains both baryta and strontia, and evolves an abundance of carburetted hydrogen. The water was collected in March 1851.

5. Is from a copious spring in the seigniorie of Berthier, and was collected in July 1853.

6. Is from the township of Caxton, and yields six or eight gallons of water a minute, besides a great abundance of inflammable gas. The carbonic acid was found to equal 1.126 parts, of which .651, or more than one half is required for the neutral carbonates present. The water was taken from the spring in October 1848.

7. Is from the seigniorie of St. Léon, and is a copious spring which, like the last, disengages inflammable gas. The carbonic acid was equal to 1.224 parts, of which .651, or not quite one half is required for the neutral carbonates found by analysis. The water was collected in October 1848.

8, 9. These are from two springs in the parish of Ste. Geneviève on the Batiscan River, and are remarkable for the large proportion of iodids which they contain. The first is known as Trudel's spring, and the second is at the ferry opposite to the church. The waters were collected in August 1853. Several other saline springs occur in the same neighborhood.

TABLE II.—WATERS OF THE SECOND CLASS.

	1	2	3	4	5	6	7	8	9
Chlorid of sodium....	11.6660	9.4600	12.2500	11.1400	8.0454	11.7750	11.4968	17.2671	11.5094
“ potassium...	.1040	.1040	.0305	.1460	undet.	.0800	.1832	.2409	undet.
“ barium.....	.....	.....	.....	.0303	.....	.....	.0019	.....	.....
“ strontium...	.....	.....	.....	.0185	.....	.....	.0019	.....	.....
“ calcium...	.1364	.0443	.2870	.2420	.0466	.0503	.0718	.6038	.2264
“ magnesium.	.2452	.4942	1.6338	.2790	.0856	.3743	.6636	2.0523	.8942
Bromid of “	.0080	.0029	.0238	.0283	undet.	.0242	.0091	.0587	.0273
Iodid of “	.0052	.0017	.0021	.0052	traces	.0039	.0046	.0123	.0183
Sulphate of lime.....	.....	.1029	.....	.....	.....	.....	.....	.....	.....
Carbonate of baryta..	.....	.....	.....	.0106	.....	.....	.....	.....	.....
“ strontia....	.....	.....	.....	.0137	.....	.....	.....	.....	.....
“ lime.....	.0330	.2980	.1264	.4520	.0470	.2160	.3493	.0120	.0180
“ magnesium	.8904	.5629	.8632	.4622	.8354	1.0593	.9388	.7506	.4464
“ iron.....	.0096	traces	traces	traces	.....	.0054	.0145	traces	traces
Silica.....	.0700	.0205	.0225	.0552	.....	.0479	.0865	undet.	undet.
Alumina.....	traces	undet.	traces	undet.	.....	.0050	.0145	“	“
In 1000 parts.....	13.1678	10.9814	14.6393	12.8830	9.0600	13.6513	13.8365	20.9987	13.1400
Specific gravity.....	1009.39	1008.78	1010.9	1009.42	.....	1010.36	1011.23	.....	.....

§ 43. Of the waters of the third class, which follow, the first four rise from the Trenton limestone, and occur on the south side of the Ottawa River, in the vicinity of the first three of the preceding section. The others are from the south side of the St. Lawrence below Montreal.

1, 2, and 3 are waters from Caledonia, and rise about two miles from the spring No. 3, of the last table. These waters were examined in September 1847. The first, which is known as the Gas spring, then yielded about four gallons of water a minute, and discharged in the same time about 300 cubic inches of carburetted hydrogen gas, whence its name. At a distance of four or five rods from this, are the second and third springs, known as the Saline and White Sulphur waters, yielding each about ten gallons a minute. The former affords a few bubbles of carburetted hydrogen gas, and is not at all sulphurous, while the latter contained a little sulphuretted hydrogen, equal to somewhat less than a cubic inch to the gallon. The temperature of the three waters was found to be respectively $44^{\circ}.4$, 45° and 46° F. The carbonic acid in 1000 parts of the Gas Spring was equal to .705; of which .356, or a little more than one half, is required for the neutral carbonates present. In the Saline spring there was found .648 of carbonic acid, being an excess of .292 over that required to form neutral carbonates; while in the Sulphur Spring, which contained in 1000 parts only .590 of carbonic acid, .349 are contained in the neutral carbonates, leaving only .141 towards the formation of bi-carbonates. For later analyses of these waters see § 46.

4. This, which is known as Gillan's spring, is from the township of Fitzroy, not very far from the last. Its waters were collected in July 1850.

5, 6. These two waters are from Varennes, and are about one hundred rods apart. The first is known as the Saline, and the second is called the Gas spring, from the large volumes of carburetted hydrogen gas which it disengages. The Saline spring contained in 1000 parts .920 of carbonic acid, of which .451 or nearly one half is required to form the neutral carbonates present. In the Gas spring was found .792 of carbonic acid, leaving thus .312 over that required to form neutral carbonates. The waters were collected in October 1848.

7. This is from Labaie du Febvre, and is known as Courchêne's spring. It evolves small quantities of carburetted hydrogen gas.

TABLE III.—WATERS OF THE THIRD CLASS.

	1	2	3	4	5	6	7	8
Chlorid of sodium	6.9675	6.4409	3.8430	6.5335	9.4231	8.4286	4.8224	5.9662
“ potassium.....	.0309	.0296	.0230	.1169	.1234	.0382	.0610	undet.
Bromid of sodium.....	.0150	.0169	.0100	.0217	.0126	.0046	undet.	undet.
Iodid of “ .....	.0005	.0014	traces	.0032	.0054	.0085	undet.	undet.
Sulphate of potash.....	.0053	.0048	.0183	.....	.....	.. ...	.....	.....
Phosphate of soda.....	.....	.....	.....	.0124	.....	.....	.....	.....
Carbonate of “ .....	.0485	.1762	.4558	.5885	.1705	.3260	1.5416	.6082
“ baryta.....	.....	.....	.....	traces	.0226	.0123	traces	.....
“ strontia.....	.....	.....	.....	“	.0140	.0096	“	.0250
“ lime.....	.1480	.1175	.2100	.1500	.3540	.3490	.2180	.1440
“ magnesia.....	.5262	.5172	.2940	.7860	.5433	.3559	.4263	.4756
“ iron.....	traces	traces	traces	traces	.0048	traces	.....	traces
Alumina.....	.0044	undet.	.0926	.0040	traces	“	undet.	undet.
Silica.....	.0310	.0425	.0840	.1330	.0465	.0540	.2120	.1140
In 1000 parts	7.7773	7.3470	4.9407	8.3473	10.7202	9.5868	7.2923	7.3330
Specific gravity.....	1006.2	1005.8	1003.7	1006.24	1008.15	1007.7	.....	.....

The water was collected in September 1852. Several other mineral springs occur in this vicinity, one of them belonging to this class, and others to the second and fourth classes.

8. This water, from the seigniori of Belœil, was collected in 1851.

§ 44. We shall now proceed to the springs which, in § 34, have been referred to the fourth class—and begin with three analyses of a mineral water from Chambly. Here, on a plateau, over an area of about two acres, the clayey soil is destitute of vegetation and impregnated with alkaline waters; which in the dry season give rise to a saline efflorescence on the partially-dried up and fissured surface. A well sunk here to a depth of eight or ten feet in the clay, which overlies the Hudson River formation, affords at all times an abundant supply of water, which generally flows in a small stream from the top of the well. Small bubbles of carburetted hydrogen are sometimes seen to escape from the water. The temperature at the bottom of the well was found in October 1861 to be 53° F., and in August 1865 to be nearly 54° F. The mean temperature of Chambly can differ but little from that of Montreal, which is 44°.6 F., so that this is a thermal water. Another alkaline and saline spring in the same parish has also a temperature of 53° F. The water of the spring here described has a sweetish saline taste, and is much relished by the cattle of the neighborhood. Three analyses have been made of its waters, the results of which are here given side by side. The first was collected in October 1851; the second in October 1852; and the third in August 1864, during a very dry season.

	I.	II.	III.
Chlorid of potassium,.....	undet.	·0324	·0182
“ sodium,.....	·8689	·8387	·8846
Carbonate “	1.0295	1.0604	·9820
“ lime,.....	·0540	·0380	·0253
“ magnesia,.....	·0908	·0765	·0650
“ strontia,.....	undet.	·0045	undet.
“ iron,.....	“	·0024	“
Alumina and phosphate,.....	“	·0063	“
Silica,.....	·1220	·0730	·0166
Borates, iodids and bromids, ..	undet.	undet.	undet.
In 1000 parts,	2.1652	2.1322	1.9917

A portion of barium is included with the strontium salt. The water contains moreover a portion of an organic acid, which

causes it to assume a bright brown color when reduced by evaporation. Acetic acid gave no precipitate with the concentrated and filtered water; but the subsequent addition of acetate of copper yielded a brown precipitate of what was regarded as apocrenate of copper. The organic matter of this and of many other mineral springs has probably a superficial origin. The carbonic acid was determined in the third analysis, and was equal in two trials to .903 and .905. The neutral carbonates in this water require .452 parts of carbonic acid.

§ 45. In the following table are given the analyses of several other waters which belong like the last to the fourth class.

TABLE IV.—WATERS OF THE FOURTH CLASS.

	1	2	3	4	5
Chlorid sodium.....	.0207	.0347	.3818	.3920	....
“ potassium...	.0496	.0076	.0067	.0318	.0169
Sulphate soda.....	....	traces.	.0215	traces.	.0188
“ potassium..	.0081	....	....	....	.0122
Carbonate soda.....	.1340	.1952	.2301	1.1353	.0410
“ lime.....	.1740	.0710	.0620	undet.	.2480
“ magnesia..	.1287	.0278	.0257	“	.0690
Iron, alumina, phos..	traces.	....	....	“	traces.
Silica.....	.0161	.0110	.0245	“	.2060
In 1000 parts.....	.5311	.3473	.7523	1.5591	....
In 10,000 parts.....	....	....	....	...	.6116

1. This spring was met with some years since in constructing a lock on the Richelieu River at St. Ours, and was enclosed in such a way that it is only accessible through a pump; so that it is impossible to determine the amount of water furnished by the spring, or its freedom from admixture. The water was obtained in November 1852, and is remarkable for the large proportion of potassium salts. 1000 parts of the water gave of alkalis determined as chlorids, 0.2250; of which 0.0565 parts, or 25.11 per cent, were chlorid of potassium. Another trial gave 24.52 per cent,; while a portion of the water taken from the spring three

weeks earlier gave a larger proportion of alkalis, equal to 0.3400 of chlorids; of which 0.0596, or 17.53 per cent, were chlorid of potassium.

2. This spring occurs on the bank of the Jacques Cartier River, a little above Quebec. It is strongly impregnated with sulphuretted hydrogen, and appears to contain a considerable proportion of borates. It was collected for analysis in the summer of 1852.

3. This water is from a spring in the township of Joly, on the opposite side of the St. Lawrence, a few miles south from the last, and like it is sulphurous, and affords a strong reaction of boric acid. It was collected for analysis in July 1853.

4. A small area of marshy ground in the seigniory of Nicolet, near the line of St. Gregoire, is, like the similar tract in Chambly, so impregnated with mineral water as to be destitute of vegetation. The water collected in a small pit dug in this locality in the autumn of 1853, was yellowish colored, and alkaline to the taste, and gave by analysis the above results. Several other alkaline springs occur in this vicinity. All of the preceding waters, with the exception of No. 2, which comes from out the Utica slates, rise, like that of Chambly, from the Hudson River formation.

5. This water, unlike the preceding, is that of a large river, the Ottawa, which drains a region occupied chiefly by ancient crystalline rocks, covered by extensive forests and marshes. The soluble matters which it contains are therefore derived in part from the superficial decomposition of these rocks, and in part from the decaying vegetation. The water which was taken at the head of the St. Anne's rapids, on the 9th of March 1854, before the melting of the winter's snows had begun, had a pale amber-yellow color from dissolved organic matter, which gave a dark brown hue to the residue after evaporation. The weight of this residue from 10,000 parts, dried at 300° F., was .6975, which after ignition was reduced to .5340 parts. As seen in the above table, one half of the solid matters in this water were earthy carbonates, and more than one third wassilica, so that the whole amount of salts of alkaline bases was .088 (of which nearly one half is carbonate of soda); while the St. Ours water, which resembles that of the Ottawa in its alkaline salts, contains in the same quantity 4.248, or more than forty-eight times as much. The alkalis of the Ottawa water equalled as chlorids, .0900, of which .0293, or 32.5 per cent, were chlorid of potassium. The results of some obser-

vations on the silica and organic matters of this river-water will be given in part III. It will be observed that in the above table the figures given for the first five waters are for 1000 parts, while those of the Ottawa are for 10,000 parts.

§ 46. In this connection may be given the analyses of two similar springs from Vermont,—the Highgate and Alburg springs. The waters were sent me in October and November 1861, and the results have already appeared in "Geology of Vermont," ii, 926. Both of these waters, when examined, were slightly sulphurous, and yielded the reactions of boric acid. The amount of carbonate of soda was estimated from the carbonate of baryta obtained by the process already mentioned in § 35.

	Highgate.	Alburg.
Chlorid of sodium .....	.402	140
Sulphate of soda.....	.042 .....	.024
Carbonate of soda.....	.235 .....	.230
“ lime.....	.024 .....	.036
“ magnesia.....	.010 .....	.022
Potash and borates.....	undet.	undet.
In 1000 parts.....	<u>.713</u>	<u>.452</u>

§ 47. On the 5th January 1865, after a lapse of more than seventeen years, I again visited the three springs of Caledonia whose analyses have been given in the table § 43, and collected their waters for a second examination. The results of my recent analyses show that considerable changes have occurred in the composition of each of these springs, and tend to confirm in an unexpected manner, the theory which I long since put forward,—that the waters of the second and third classes owe their origin to the mingling of saline waters of the first class with alkaline waters of the fourth class. It will be observed that the three Caledonia waters in 1847 were all alkaline, though the proportions of the carbonate of soda were unlike. Sulphates were also present in all of them, though most abundant in the Sulphur spring, which, although holding the smallest amount of solid matters, was the most alkaline. In January 1865, however, the first and second of these waters had ceased to be alkaline, and contained, instead of carbonate of soda, small quantities of earthy chlorid, causing them to enter into the second class. They no longer contained any sulphates, but, on the contrary, portions of baryta and strontia. Only the Sulphur spring, which in 1847 contained the largest proportion of carbonate of soda and of sul-

phates, still retained these elements, though in diminished amounts, and was feebly impregnated with sulphuretted hydrogen. If we suppose these waters to arise from the commingling of saline waters like those of Whitby and Lanoraie, containing earthy chlorids and salts of baryta and strontia, with waters of the fourth class, holding carbonate and sulphate of soda, it is evident that a sufficient quantity of the latter water would decompose the earthy chlorids and precipitate the salts of baryta and strontia present; while an excess would give rise to alkaline-saline waters containing sulphate and carbonate of soda, such as were the three springs of Caledonia in 1847. A falling-off in the supply of the sulphated alkaline water has however taken place, and the result is seen in the appearance of chlorid of magnesium and of baryta and strontia in two of the springs, and in a diminished proportion of carbonate of soda in the Sulphur spring.

These later analyses being directed chiefly to the determination of these changes, no attempt was made to determine the potassium, iodine, and bromine. For the purposes of comparison, the two series of analyses are here put in juxtaposition; the elements just mentioned being included with the chlorid of sodium, and the figures reduced to three places of decimals. The precipitate by a solution of gypsum from the concentrated and acidulated water was regarded as sulphate of strontia, and calculated as such, but was in part sulphate of baryta.

TABLE V.—SHOWING THE CHANGES IN THE CALEDONIA SPRINGS.

	1. Gas Spring.		2. Saline Spring.		3. Sulphur Spring.	
	1847.	1865.	1847.	1865.	1846.	1865.
Chlor. sodium....	7.014	6.570	6.488	6.930	3.876	3.685
“ magnesium....	....	.024	....	.026	....	....
Sulph. potash ....	.005	....	.005	....	.018	.021
Carb. soda .....	.048	....	.176	....	.456	.091
“ lime.....	.148	.096	.117	.095	.210	.077
“ magnesia..	.526	.455	.517	.469	.294	.228
“ strontia....	....	.009	....	.012	....	....
Silica.....	.021	.020	.042	.015	.084	.021
In 1000 parts....	7.762	7.174	7.345	7.547	4.938	4.123

In the recent analyses of these waters, the carbonic acid in the Gas spring was found to equal for 1,000 parts, .671; of which .278 were required for the neutral carbonates. The Saline spring contained .664 of carbonic acid; of which .290 go to make up the neutral carbonates. The Sulphur spring, in like manner, gave of carbonic acid .573; while the neutral carbonates of the water required only .191. All of these waters, in January 1865, thus contained an excess of carbonic acid above that required to form bicarbonates with the carbonated bases present; while the analyses of the same springs in 1847, showed, as we have seen in § 43, a quantity of carbonic acid insufficient for the formation of bicarbonates. The questions of this deficiency, and of the variation in the amount of carbonic acid in these and other waters, will be considered in the third part of this paper.

§ 48. The waters of our fifth and sixth classes, as defined in § 34, are distinguished by the presence of sulphates; the former being acid, and the latter being neutral waters. In the fifth class the principal element is sulphuric acid, associated with variable and accidental amounts of sulphates of alkalis, lime, magnesia, alumina, and iron. Apart from the springs of this kind which occur in regions where volcanic agencies are evidently active, the only ones hitherto studied are those of New York and western Canada; which issue from unaltered, and almost horizontal Upper Silurian rocks. (§ 31.) The first account of these remarkable waters was given in Silliman's Journal in 1829 (vol. xv, p. 238), by the late Prof. Eaton, who described two acid springs in Byron, Genesee Co., N. Y.; one yielding a stream of distinctly acid water sufficient to turn a mill-wheel, and the other affording in smaller quantities a much more acid water. The latter was afterwards examined by Dr. Lewis Beck (Mineralogy of New York, p. 150). He found it to be colorless, transparent, and intensely acid, with a specific gravity of 1.113; which corresponds to a solution holding seventeen per cent of oil of vitriol. No chlorids, and only traces of lime and iron, were found in this water, which was nearly pure dilute sulphuric acid. Prof. Hall (Geology of New York, 4th District, p. 134) has noticed, in addition to these, several other springs and wells of acid water in the adjacent town of Bergen. Farther westward, in the town of Alabama, is a similar water, whose analysis by Erni and Craw will be found in Silliman's Journal [2] ix, 450. It contained in 1000 parts about 2.5 of sulphuric acid, and 4.6 parts of sulphates, chiefly of lime, magnesia, iron, and alumina. In this, as in

the succeeding analyses, hydrated sulphuric acid, SO_3HO , is meant.

The earliest quantitative analyses of any of these waters were those by Croft and myself of a spring at Tuscarora, in 1845 and 1847, of which the detailed results appear in Silliman's Journal [2] viii, 364. This, at the time of my analysis in September 1847, contained in 1000 parts, 4.29 of sulphuric acid, and only 1.87 of sulphates; while the previous analysis by Prof. Croft gave approximatively 3.00 of neutral sulphates, and only about 1.37 of sulphuric acid. Similar acid waters occur on Grand Island above Niagara Falls, and at Chippawa.

All of these springs, along a line of more than 100 miles from east to west, rise from the outcrop of the Onondaga salt-group; but in the township of Niagara, not far from Queenston, are two similar waters which issue from the Medina sandstone. One of these is in the southwest part of the township, and fills a small basin in yellow clay, which, at a depth of three or four feet, is underlaid by red and green sandstones. The water, which, like those of Tuscarora and Chippawa, is slightly impregnated with sulphuretted hydrogen, is kept in constant agitation from the escape of inflammable gas. It contained in 1000 parts about two parts of free sulphuric acid, and less than one part of neutral sulphates. This water was collected in October 1849, and at that time another half-dried-up pool in the vicinity contained a still more acid water. Another similar spring occurs near St. Davids in the same township.

In connection with the suggestion made in § 31 as to their probable origin at great depths, it would be very desirable to have careful observations as to the temperature of these acid springs. When, on the 19th October 1847, I visited the Tuscarora spring, the water in two of the small pools had a temperature of 56°F .; but on plunging the thermometer in the mud at the bottom of one of these it rose to $60^\circ.5$.

§ 49. It appears from a comparison of the analysis of Croft with my own that the waters of the Tuscarora spring underwent a considerable change in composition in the space of two years; the proportion of the bases to the acid at the time of the second analysis being little more than one third of that in the analysis of Croft. This change was indeed to be expected, since waters of this kind must soon remove the soluble constituents from the rocks through which they flow, and eventually become, like the water

from Byron, little more than a solution of sulphuric acid. The observations of Eaton at Byron, and my own at Tuscarora, show that half-decayed trees are still standing on the soil which is now so impregnated with acid waters as to be unfit to support vegetation. Reasoning from the changes in composition, it may be supposed that these waters were at first neutral, the whole of the acid being saturated by the calcareous rocks through which they must rise. It was from this consideration that I was formerly led to ascribe to the action of these waters the formation of some of the masses of gypsum which appear along the outcrop of the Onondaga salt-group (Silliman's Journal [2], vii, 175). That waters like those just mentioned must give rise to sulphate of lime by their action on calcareous rocks is evident; and some of the deposits of gypsum in this region, as described by good observers, would appear to be thus formed. So far however as my personal observations of the gypsums of western Canada have extended, they appear to be in all cases cotemporaneous with the shales and dolomites with which they are interstratified, and to have no connection with the sulphuric-acid springs which are so common throughout that region. (Silliman's Journal [2], xxviii, 365, and Geology of Canada, 352.)

§ 50. We have included in a sixth class the various neutral saline waters in which sulphates predominate, sometimes to the exclusion of chlorids. The bases of these waters are soda, potash, lime, and magnesia; which are usually found together, though in varying proportions. For the better understanding of the relations of these sulphated waters, it may be well to recapitulate what has been said about their origin; and to consider them, from this point of view, under two heads.

First, those formed from the solution of neutral sulphates previously existing in a solid form in the earth. Strata enclosing natural deposits of sulphates of soda and magnesia, sometimes with sulphate of potash, (§ 17, § 19,) afford the most obvious source of these waters. The frequent occurrence of gypsum however points to this salt as a more abundant source of sulphated waters. Solutions of gypsum may in some case exchange their lime for the soda of insoluble silicates, or this salt may be decomposed by solutions of carbonate of soda (§ 7, § 19). The decomposition of the sulphate of lime by hydrous carbonate of magnesia, as explained in § 21, is doubtless in many cases the source of sulphate of magnesia, which is more frequently than sulphate of soda a predomi-

nant element in mineral waters. In connection with a suggestion made in the section last cited, it may be remarked that I have since found that predazzite, in virtue of the hydrate of magnesia which it contains, readily decomposes solutions of gypsum holding carbonic acid in solution, and gives rise to sulphate of magnesia.

In the second place, sulphuric-acid waters, like those described in § 47, by their action upon calcareous and magnesian rocks, or by the intervention of carbonate of soda, may, as already suggested, give rise to neutral sulphated waters of the sixth class. It is evident also that waters impregnated with sulphates of alumina and iron from oxydizing sulphates, as mentioned in § 28, may be decomposed in a similar manner, and with like results.

Neutral sulphated waters generated by any of the above processes, are evidently subject to admixtures of saline matters from other sources, and may thus become impregnated with chlorids and carbonates. Indeed it is rare to find waters of the sixth class without some portion of chlorids; and a transition is thus presented to the waters of the first four classes, in which also portions of sulphates are of frequent occurrence. The presence of sulphates being one of the conditions required for the generation of sulphuretted hydrogen (§ 10), we find that the waters of the sixth class are very often sulphurous.

§ 51. Waters of the sixth class are very frequently met with in the palæozoic rocks of New York and western Canada, and are probably derived from the gypsum which is found in greater or less abundance at various horizons, from the Calciferous sand-rock to the Onondaga salt-group. It is however not improbable that the sulphuric-acid waters which abound in this region (§ 48) may, by their neutralization, give rise to similar springs. In the waters of the district under consideration, the sulphate of lime generally predominates over the sulphates of the other bases, and chlorids are frequently present in considerable quantities. For numerous analyses of these waters, see Beck, *Mineralogy of New York*. The results of an examination of the Charlotteville spring, remarkable for the amount of sulphuretted hydrogen which it contains, will be found in *Silliman's Journal* [2], viii, 369. A copious sulphur spring which issues from a mound of calcareous tufa in Brant, C.W., overlying the Corniferous limestone, is distinguished by the absence of any trace of chlorids; in which respect it resembles the acid waters of the fifth class from the adjacent region. A partial analysis of a portion of it collected in 1861, gave for

1000 parts, sulphate of lime 1.240, sulphate of magnesia .207, and carbonate of lime .198. From a slight excess in the amount of sulphuric acid, it is probable that a little sulphate of soda was also present.

Of waters of this class, in which sulphate of magnesia predominates, but few have yet been observed in this country. A remarkable example of this kind from Hamilton, C. W., was examined by Prof. Croft of Toronto, and described by him in the *Canadian Journal* for 1853 (page 153). It had a specific gravity of 1006.4, and gave for 1000 parts,

Chlorid of sodium.....	5698
Sulphate of soda	16985
“ lime.....	11246
“ magnesia	47799
	81128

The rocks exposed at Hamilton include the Medina sandstone and the Niagara limestone, with the intermediate Clinton group. Along the outcrop of the latter, crystalline crusts of nearly pure sulphate of magnesia are observed to form in many localities, during the dry season of the year. (*Geology of Canada*, p. 460.)

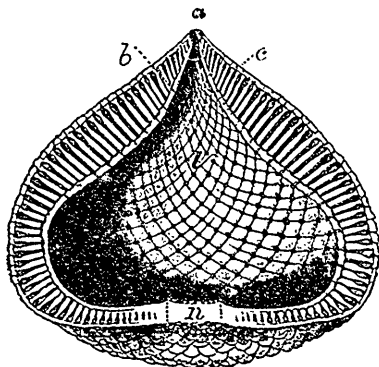
According to Emmons, the post-tertiary clays near Crown Point, on the western shore of Lake Champlain, are during dry weather covered with efflorescences of sulphate of magnesia, which impregnates several springs in the vicinity. The water of one of these, according to Emmons, had a specific gravity of 1014.0, and contained in 1000 parts, 18.78 of saline matter, which was chiefly sulphate of magnesia, with some sulphate of lime (cited by Beck, *Mineralogy of New York*, p. 252). The strata underlying the clays of this region belong according to the State geological map, to the Potsdam, Calciferous, and Trenton formations; but the source of the magnesian salt is, not improbably, to be found in the clays themselves.

In the third and concluding part of this paper it is proposed to notice briefly some of the more important points in the chemistry of the various waters which have been here described, and to inquire into their geological relations.—*Silliman's Journal*.

NOTES ON SOME OF THE MORE REMARKABLE
GENERA OF SILURIAN AND DEVONIAN FOSSILS.

By E. BILLINGS, F.G.S.

Genus RECEPTACULITES, DeFrance.



1.

1.—Diagram of the structure of *Receptaculites* as it would be shown in a vertical section through a sub-conical species. *a*, the aperture in the summit; *b*, the endorhin or inner integument lining the central cavity; *c*, the ectorhin or external integument; *n*, the usual position of the nucleus; *v*, the great internal cavity. The unshaded bands running from the ectorhin to the endorhin represent the tubes.

The structure and zoological position of *Receptaculites* have been more or less elaborately investigated by Goldfuss, Eichwald, Roemer, Salter, Hall, and other eminent observers, and yet, owing to the imperfection of the materials, a great deal remains to be done before the various questions involved in the relations of this curious genus can be regarded as positively settled. Since the publication of Salter's paper in the first Decade of our Geological Survey, numerous specimens of several distinct species have been collected in the Silurian rocks of Canada, and I am, by the study of these, now enabled to furnish a few additional details. The principal new points are, the perforated structure of the internal integument, the existence (in most, if not in all, of the species) of a great central cavity and an orifice in the upper side. The flat watch-shaped specimens which are usually figured as constituting the whole of the body, are probably only the basal portion of the body-wall of the discoid species.

The genus may be described as consisting of organisms, which, when full grown and perfect, are of a discoid, cylindrical, ovate, or globular shape, hollow within, and usually, if not always, with an aperture in the upper side. In or near the centre of the lower side there is generally to be seen a small rounded protuberance, indicating, most probably, the position of the primitive cell or nucleus from which the animal commenced its growth. In some species the lower side is more or less concave, and often the nucleus is not at all elevated above the surface adjacent thereto. Its place, however, in the absence of any other guide, may generally be found by observing the point towards which the spiral lines or rows of plates on the outer surface converge. The body-wall is of a somewhat complex structure. It consists of three parts,—an external and an internal integument, and, between these, the peculiar tubular or spicular skeleton presently to be described. The external integument may be called ‘the ectorhin,’ and the internal ‘the endorhin.’

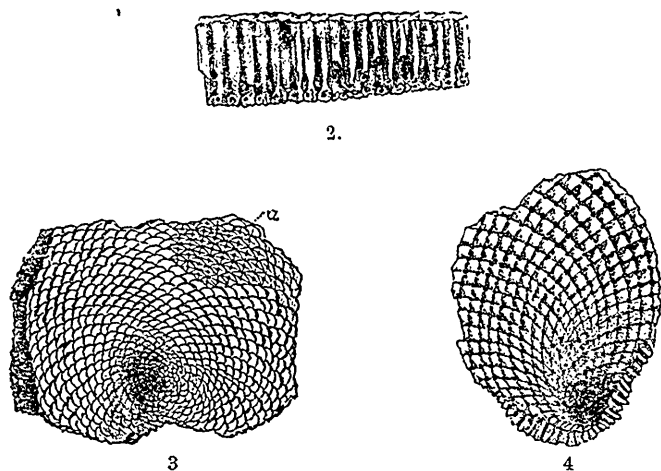
The ectorhin is usually composed of numerous small rhomboidal plates closely fitting together, and arranged in curved rows which radiate in all directions from the nucleus outwards to the peripheral margin of the base, and thence, ascending upwards, converge to the edge of the aperture in the upper side. Two or three of those rows of plates (the precise number is not yet determined) originate in the nucleus, and, as they diverge from each other, new rows are introduced between them. The number of rows diminish again on the upper side according as they converge towards the apex of the fossil. The plates at and immediately around the nucleus, and also towards the centre of the upper side, are somewhat smaller than they are at the widest part or middle region of the body. It seems probable that, in some of the species, this integument was of a flexible, coriaceous consistence. In others the plates were solid. In *R. occidentalis* (Salter), when silicified specimens are treated with acid the plates are easily separable, and, therefore, although in close contact, they were not anchylosed together.

The endorhin is also composed of small rhomboidal plates arranged in curving rows; but it differs from the ectorhin in being perforated by numerous small circular orifices, one of which is situated at each point where the angles of four plates meet. From the centre of each of the plates of this integument there radiate four small canals, one proceeding straight to the middle of each of the sides of the plate, where it communicates with a similar canal

in the adjoining plates. Each one of these plates is, therefore, connected by these canals with the four plates in contact with it. The canals are excavated in the substance of the plates, and communicate with the central canal of the transverse tubes. The canals are not always perfectly circular, but are often flattened or irregularly circular. The endorhin varies greatly in the extent to which it is developed. In some specimens the plates are well-defined and rhomboidal, with perfectly circular pores at the angles. In others the plates are not at all defined, the ectorhin being one continuous integument without sutures, but always with the full complement of pores. The latter in such specimens are not all circular, but are variously shaped orifices, sometimes with rough edges. There are also specimens in which the endorhin consists of only a thin film capping, as it were, the tubes and inclosing the canals, the pores being proportionally larger than they are in those with well-developed plates. The end of each tube, in these specimens, forms an irregular, rounded tubercle instead of a rhomboidal plate.

The tubular skeleton above alluded to consists of numerous small, straight, rarely curved, cylindrical tubes or hollow spicula, placed parallel to each other and at right angles to the plane of the body-wall of which they form the greater portion. They connect, and at the same time keep asunder, the ectorhin and the endorhin. One of these tubes springs from the centre of each plate of the ectorhin: it is, at its base, or next to the ectorhin, very slender, but enlarges so as to attain its full thickness at about one fourth of its length, and then remains at the same diameter throughout until it reaches the endorhin, by a single plate of which its inner extremity is, as it were, capped. The outer extremity of each tube has four small slender stolons, one proceeding to each of the four angles of that particular plate of the ectorhin from the centre of which it (the tube) springs. It there seems to form a connection with the stolons of the three adjacent plates whose angles meet at that point. The stolons are so arranged that one of them always points inwards towards the nucleus, and another on the opposite side of the tube outwards or upwards. It is proposed to call these the radial stolons; they form continuous lines radiating in all directions away from the nucleus. The other two stolons of each tube project at right angles to the direction of the radial stolons; they form circles round the nucleus, and may therefore

be called the cyclical stolons. The connection of all these different parts may be better understood by studying the following figures.

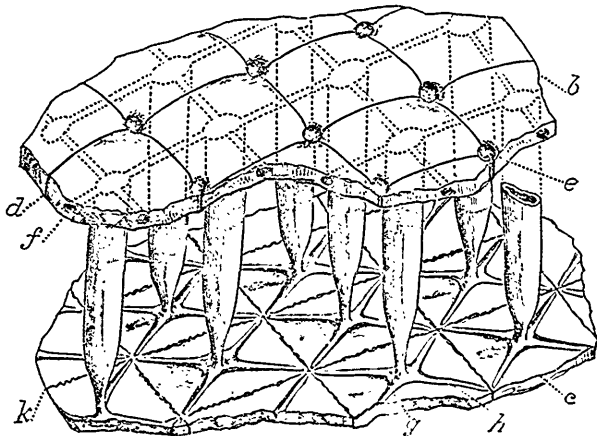


2. A small portion of *R. occidentalis* showing the tubes. 3. A part of the lower side of the same species showing the nucleus and ectorhin. 4. A fragment of the same, showing the endorhin, the pores at the angles of the plates, and the nucleus, which, on this side, is usually deeply concave.

At the lower side of fig. 2, is shown the ectorhin and the apertures in the hollow stolons, broken off in the specimen. The apertures are slightly enlarged in the figure. In fig. 2, the usual aspect of the central portion of the lower side of this species is given. It will be seen that the greater number of the plates are not truly rhomboidal, but approach the form of a spherical triangle with two of the sides concave. This form of the plates frequently occurs. The convex side of such plates is always outwards towards the periphery of the fossil, and the acute angle formed by the two concave sides always directed towards the nucleus. This shows that the consolidation of the plates commenced at the nucleus and gradually extended outwards. In many specimens the plates are all perfectly rhomboidal, and in such they may have solidified simultaneously all over the body. One corner of the specimen at *a* is represented as denuded of the ectorhin, showing the various markings beneath, which will be hereafter explained by other figures. By fig. 4 is represented the ordinary

appearance of the endorhin of silicified specimens when cleared of the limestone matrix by treatment with acid. Although the pores have been seen in this species only, yet it seems quite probable that they occur in all others of the genus

In the diagram fig. 5 the tubes are placed proportionately much farther apart than they are in any known species, in order to exhibit the structure with the greater clearness. The endorhin is drawn as if it were transparent to show the position of the tubes beneath it. The dotted lines give the outlines of the upper portions of the tubes, and also define the course of the endorhinal canals,—four radiating from the top of each tube. The endorhinal pores—one situated at each of the points where the angles of four plates meet—penetrate through the endorhin into the space between the tubes, and not into the tubes themselves, as might be supposed from a superficial examination. In the ectorhin the rough lines *k* represent the sutures between the plates; and it will be observed that they have the same direction as the endorhinal sutures in the upper part of the figure. The stolons have not the



5. Diagram to explain the structure of the body-wall of *Receptaculites*. *b*, the endorhin; *c*, the ectorhin; *d*, suture between the plates of the endorhin; *e*, endorhinal pore; *f*, endorhinal canal; *g*, radial stolon; *h*, cyclical stolon; *k*, suture between the plates of the ectorhin.

same direction as the endorhinal canals, but are, as it were, turned one eighth round, so that the two directions are inclined to each

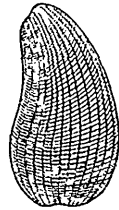
other at an angle of 45° . The stolons run along the inner surface of the ectorhin, but the endorhinal canals are excavated in the substance of the endorhin. The space between the tubes is almost always filled with the rock of the same kind as that in which the fossil is imbedded. In perfect specimens, the rock, while it was still in the condition of soft mud, must have found its way through the aperture in the upper side into the great central cavity, and thence through the endorhinal pores into the spaces between the tubes. In general the upper side or vault, as it may be called, over the central cavity is not preserved, and the specimen then consists of the whole or a portion of the base with the nucleus, as in figs. 3, 4. These are also filled with matrix; the soft ooze having entered not only through the pores, but also through the broken margin. It is probable that the animal lived with its base partly buried, a portion of the vault with the aperture projecting above the surface of the mud. During the life the central cavity was perhaps kept free from sediment by currents of water which the animal had the power of exciting. But as soon as the currents ceased (with vitality), the mud would enter freely. The vault would also soon fall to pieces, and the fragments of all those individuals of which it (the vault) projected above the surface of the sediment would be soon scattered, while the partly buried base would be preserved.

The specimen represented by fig. 6 is a fragment of the ectorhin of *R. calciferus*, from the Calciferous formation, Mingan Islands. It shows only the inner surface on which the stolons are still preserved, but the tubes are worn nearly to their bases. It is rare to find specimens in that condition; and this one was not suspected to be a *Receptaculites* for several years after its discovery, until a large portion of the base of an individual of *R. occidentalis* was found, which, by having been slowly weathered down from the upper side, retains the tubes over an area of several square inches, while a considerable space around the nucleus is covered with the squares formed by the stolons, precisely as in this example. Fig 7 is a cast of the inner surface of the ectorhin of *R. Oweni* (Hall), from the Lower Silurian rocks of Illinois. The integument itself is totally removed. The vertical lines are the impressions of the radial stolons, while the more irregular and slightly curved transverse lines are the imprints of the cyclical stolons. The dark points are the apertures of the cylindrical perforations in the rock once occupied by the tubes now entirely removed. On following any one of the lines, it will

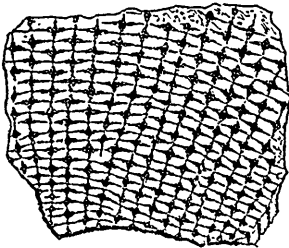
be seen that there is, between every two of the orifices, a point where two of the lines cross without an orifice at their intersection. Each one of these marks the point where the angles of four plates met. Four stolons also met at each of these points. This will be readily understood by comparing fig. 5. In specimens in this state of preservation we see no traces of the sutures between the plates, as the whole substance of the ecto-rhin—plates, sutures and all—is destroyed.



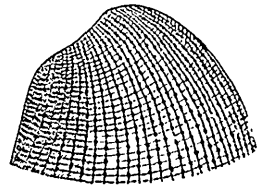
6.



8.



7.



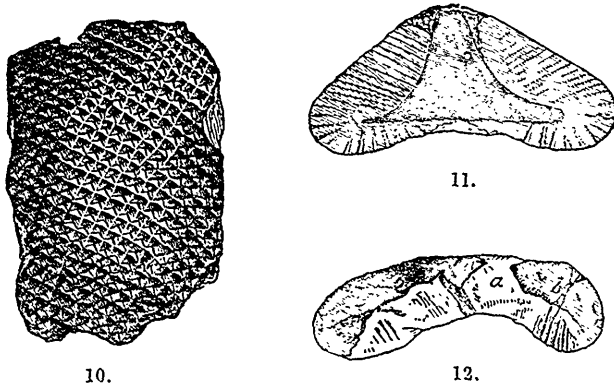
9.

6. Fragment of *R. calciferus* (Billings). 7. *R. Oweni* (Hall). 8 and 9 *Tetragonis Murchisonii* (Eichwald).

Fig. 8 is a reduced outline of *Tetragonis Murchisonii*, from Eichwald's 'Urwelt Russlands,' pl. iii, fig. 18. It does not show all the lines given in the original figure, as they could not well be represented on so small a scale. Fig. 9 is the upper part of the same figure, of the size of the original. The vertical lines are the impressions of the radial stolons, and the finer transverse lines the grooves of the cyclical stolons. By comparing fig. 7, it will be seen that the grooves in both figures have precisely the same arrangement; that is to say, the dark points, representing the openings of the cylindrical cavities, once occupied by the tubes, occur at each alternate crossing of the grooves. It would appear,

therefore, that Eichwald's genus *Tetragonis* was founded on a species of *Receptaculites*, with the ectorhin removed. The genus *Ischadites* also exhibits very similar markings, as may be seen by comparing the figures of *I. Koenigii* (Murch.), on pl. 12, 'Siluria,' and the following of *R. Canadensis*.

The specimen represented by fig. 10 has been figured by me in the Geology of Canada, p. 304, under the name of *Ischadites Canadensis*. It is the cast of the inner surface of the ectorhin, and differs remarkably from the similar specimen of *R. Oweni* (*ante*, fig. 7). It is deeply pitted all over with sub-quadrangular or rhomboidal depressions, the form of each cavity being such as would be made by the impression of a small four-sided pyramid. In the bottom of each is a small rounded orifice, from which radiate three grooves to three of the angles of the square. These,



10. *R. Canadensis* (Billings). 11. *R. Iowensis* (Owen). 12. *R. Jonesii* (Billings).

I have not the least doubt, are the grooves of three of the stolons. The absence of the fourth stolon may be accounted for in this way. Among the detached silicified tubes of *R. occidentalis* which are found in the sediment, left at the bottom of the vessel, after dissolving specimens of limestone holding these fossils in acid, numerous specimens have been collected with only three stolons in contact with the plate or at the end of the tube, but with the fourth a small distance from the end. It is evident that in casts of the inner surface of the ectorhin of specimens with all the tubes thus constructed, there would be only the three grooves of the terminal stolons visible on the surface, the fourth being

buried beneath the surface. I have also ascertained that this fourth stolon is in *R. occidentalis*, one of the radials, and always when it can be seen *in situ*, the one pointing outwards away from the nucleus.

Fig. 11 is a vertical section of *R. Jonesii*, a small species which occurs in the upper part of the Lower Helderberg rocks of Gaspé. The shaded bell-shaped area is the central cavity. It is distinctly observed in several others of the same species. It will be seen that the body-wall in the vault above and on the sides of the cavity is thicker than it is in the base, but the tubes are much more slender. They here assume the form of the elongated connecting spicula of the true sponges. Fig. 12 is a similar section, though a specimen of *R. Lowensis* from the Trenton limestone at Ottawa. At *a*, the central cavity is distinctly shown, filled with the grey limestone matrix, which has also found its way between the tubes in the base of the fossil. The shaded portions *b b* are replaced by a reddish magnesian spar. The under side of the specimen is deeply concave, and the peripheral margin is so convex as to resemble a cylinder coiled into a ring. The aperture in one specimen of *R. Jonesii* is rounded, and resembles the umbilicus of an apple.

The figures given by different authors of foreign species show a considerable range of variation in the general form, and apparently also in the structure of the body-wall. The details given in this paper have been made out principally by the study of numerous specimens of *R. occidentalis*, which is undoubtedly congeneric with *R. Neptuni*, the typical form of the genus. In others, such as *Tetragonis sulcata* and *T. parvipora* (Eichwald), there appears to be a transition to species in which the ectorhin was a soft coriaceous integument, not distinctly plated, although connected with the interior by tubes or spicula. The genus *Tetragonis*, instead of becoming obsolete, might be retained for some of the species which have a structure different from that of *R. Neptuni*.

As to the zoological rank of *Receptaculites* there yet remains much diversity of opinion. At the present time the most ably supported view is that which places the genus in the Foraminifera near *Orbitolites*. Seen in this light, the diagram at the head of this paper would represent the soft and not the hard parts of the animal. If this be the true interpretation, then we must suppose that outside of the ectorhin there was a layer of shell, and another layer covering the endorhin, or lining the great central cavity.

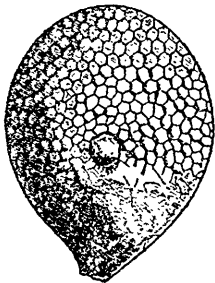
All the space between the tubes was also a compact mass of shelly substance similar to that of the Foraminifera. But not a vestige of any such shell has ever been discovered. The space between the tubes is invariably filled with the same kind of rock as that in which the specimens are imbedded, while all that is, in this paper, described as constituting the skeleton is in the same mineral condition as are the hard parts of the corals, crinoids and molluses found buried in the same beds. In the ordinary limestone whenever the solid portions of the other fossils are replaced either by calcareous spar or silica, or partly by one and partly by the other, the skeleton of *Receptaculites* is always found converted into the same mineral substances. And again in the magnesian limestones where the hard parts of fossils are, in general, totally removed, so that the cavities once occupied by them remain empty, we find *Receptaculites* in the same condition. We have not the tubes themselves, but only the cylindrical perforations in the rock which they at one time filled, while the existence of the stolons is only indicated by grooves such as those represented in figs. 7, 9, 10. These facts seem to prove clearly that the space between the tubes was not filled with shell substance, but either empty, or entirely, or partly full of soft matter, which was immediately dissipated after the death of the animal, and its place occupied by the soft mud in or on which the creature lived. Were it otherwise we would now find the space in question a compact mass of calcareous spar or amorphous siliceous matter, while the tubes (or cells as they would be in that case) might be filled with limestone. In the magnesian specimens the ectorhin seldom, if ever, remains; and in species with flat plates the form (of the plates) can rarely be made out, the only markings on the surface being the grooves of the stolons. But where the plates were deeply concave the position of the sutures is indicated by more or less strongly elevated ridges enclosing rhomboidal depressed spaces with a tube-cavity in the centre. Fig. 10 represents a fragment of *R. Canadensis* in that state of preservation. The rhomboids in this case are not the plates themselves, but only their impressions. In describing such specimens, the tubes are sometimes spoken of as having rhomboidal openings, but this is an error; the tubes when perfect, as can be proved by hundreds of specimens, are not open at all, but completely closed, at one end by the ectorhin and at the other by the endorhin. They all, however, communicate with each other through the stolons and endorhinal canals.

Were the tubes of *Receptaculites* to be closely crowded together so that their walls would everywhere be in contact, and no space between them, then the structure would be similar to that of *Orbitolites*, but with the system of connecting stolons arranged on a different plan. The genus would then also closely resemble *Dactylopora*; but I do not yet see that the evidence is sufficient to prove clearly that the tubes are strictly the homologues of the cells of any group of the Foraminifera. They appear to me to be more nearly related to the connecting spicula of the Spongidae. Each tube with its cylindrical shaft, and plate at each extremity, resembles not remotely a birotulate spiculum. Or it might perhaps with more probability be described as consisting of two spicula united at their points. Thus the ectorhinal plate with the four stolons may be a peculiar form of the foliato-peltate spicula, of which many different kinds are figured by Bowerbank. The cylindrical shaft may be a spiculum approaching the acute or acerate varieties with its point inserted into the nucleus of the foliato-peltate spiculum. Most sponge spicula are hollow; and we know how often it happens in the structure of the animal kingdom that organs may at one time subservise one function, and elsewhere a very different function. The cylindrical cavity, which in the spicula of the ordinary sponges seems to be functionless, may in *Receptaculites* be transformed into a canal for the transmission of fluids. But although the cavities of all the tubes in *Receptaculites* communicate with each other through the endorhinal canals, and perhaps through the stolons also, they may not constitute a canal-system. The so-called tubes are extremely slender, and may be solid in some species.

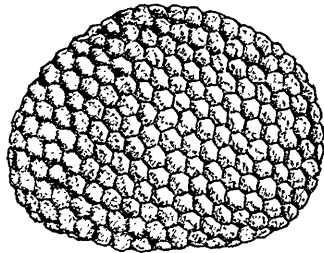
On comparison it will be found that the general form of *Receptaculites* and structure of its body-wall is almost precisely that of the seed-like body that plays so important a part in the development of *Spongilla*. This consists of a small ovate or spherical sac with an aperture on one side leading into the cavity within. The enclosing wall consists of a coriaceous membrane on the outside of which there are arranged, perpendicularly to the surface, numerous small birotulate spicula, exactly as the tubes of *Receptaculites* are arranged on the endorhin. The outer extremities of these spicula give off at right angles a number of small spines corresponding to the stolons above figured. These spines coalesce, and (if I understand the figures rightly) become connected together, so that they form by their union a plate similar to that of

Receptaculites, only that it is hexagonal. The plates of all the spicula enlarge until all come into contact, and thus an outer tessellated integument corresponding to the ectorhin is formed. In this stage a section through the seed-like body shews an inner integument (or endorhin), and an outer plated integument (or ectorhin), the two being separated and at the same time connected by the pillar-like cylindrical shafts of the spicula representing the tubes of *Receptaculites*. The space between the tubes is, according to some authors, filled with a gelatinous silicious matter; but Bowerbank says he did not detect this substance in the specimens examined by him. This little sac or cell is a *Receptaculites* in miniature, and it is also one of the embryonic stages of a sponge. When we consider that the full grown and adult individuals of many of the long extinct tribes of animals never attained in their structure a more advanced organization than that exhibited by the embryos of orders living at the present day, it does not seem surprising that we should find in the palæozoic rocks a sponge which although often of large size, never became more highly developed, than is the recent genus *Spongilla*, when it has only advanced to the sac-like stage above described. It is not intended to assert here positively that *Receptaculites* is a sponge, or to determine the question of its zoological rank one way or the other, but only to direct attention to such peculiarities in its structure as appear to me worthy of being taken into account in the investigation.

Genus PASCEOLUS, Billings.



13.



14.

13. *P. Halli*. From the Middle Silurian, Anticosti. 14. *P. globosus*.
Trenton limestone, Ottawa.

The fossils of this genus are of an ovate or globular form covered with an integument of small polygonal plates (?) and with one

or more circular apertures. Two species are at present known to occur in the Silurian rocks of Canada, both of which are above figured.

P. Halli is of an ovate form, from one to two inches in length and about one-fourth less, in width. At one end there is a narrow prolongation which, most probably, constituted the pedicle by which the body was attached to the bottom. No trace of any other point of attachment can be seen; and it is almost certain, therefore, that this smaller extremity is the base. A little below the mid-height of the body there is a small circular elevation which appears to mark the place of an orifice; but as the integument is not preserved in this part, it cannot, at present, be positively determined whether there was an aperture here or not. All that can be said is that there appears to have been an orifice where this elevation occurs. The specimens collected are all casts of the interior, but of the one figured a portion of the integument remains attached to the matrix. It is about one-third of a line in thickness, of a translucent, horny color, the surface covered with minute corrugated wrinkles just visible to the naked eye. No sutures can be distinguished, and the form of the plates can only be made out as so many obscure convexities on the outside. But where the integument is removed the cast shows the place of the sutures most distinctly, and that the plates were deeply concave on the inside. The polygonal spaces, in the above figure, represent only the outlines of the casts of the inner surfaces of the plates, and, as those are deeply concave, of course the whole surface of the cast of the fossil is covered with small convex elevations. In some places these are so exceedingly convex that they present the appearance of a mass of small globular cells just so much pressed together as to produce the hexagonal outline along the boundary of contact. Many of these elevations have a small round knob in the centre with an obscure ridge radiating to the middle of each of the sides, where they meet similar ridges from the other convexities. These markings are very obscurely developed, and in some places cannot be seen at all.

P. globosus only differs from *P. Halli* in being larger and of a spherical shape. The specimens are sometimes three inches across, but the common size is about two inches. They are, usually, more or less compressed and distorted, in general of a hemispherical shape, the base flattened as if the body had been a soft globular sac of matter which had settled down by its own weight. They are, however, occasionally found of a nearly spherical form. On

one side (the flattened side) of a specimen in the cabinet of Dr. J. A. Grant, of Ottawa, there is a small elevation which may have been the point of attachment. No orifices have yet been made out, but it must be observed that no specimen has been collected in which the whole of the surface can be examined. None that I have seen have a vestige of the integument remaining. The plates (or rather their impressions) are, in these specimens, for the greater part, strongly convex and precisely like those of *P. Halli*, only larger. In some they are partly concave and partly convex or flat. Individuals also occur which have them either convex, all flat, or all concave. Yet as these occur together in the same localities, I think them all one species. They have, as yet, been found only at the city of Ottawa in the Trenton limestone.

In one piece of shale scarcely a yard square, I collected about fifty individuals, but although they occur thus abundantly in certain spots, good specimens are exceedingly rare.

This genus was first described by me in the Report of the Geological Survey of Canada for 1857, p. 342, and placed among the fossils of uncertain class. The two species above figured are also there described. They have been on exhibition in the cases of our museum for the last ten years, and have been examined by a great many of the naturalists of all countries. But I do not think we yet know to what class they belong. *P. Halli* and *Ischadites Canadensis* are figured on p. 304, of the Geology of Canada, as members of the *Tunicata*. The latter, however, is a true *Receptaculites*. It is barely possible that the former may be a tunicate, but we have no positive evidence that it is.

Eichwald, in his *Lethaea Rossica*, has described and figured two species, *Cyclocrinus Spaskii* and *C. exilis*, which appear to me to be either congeneric with our two, or, at least, to belong to the same family. Both of Eichwald's species are small globular bodies covered with hexagonal or pentagonal plates. The plates of *C. Spaskii* have a tubercle in the centre and a number of obscure rounded ridges radiating to the sides. He says there is a small oral orifice on one side, and on the side opposite, a rudimentary pedicle. One of his figured specimens is covered with a tubular incrustation consisting of small cells which he considers to be a part of the integument itself. It may be, however, a coral. A fragment of one of the specimens of *P. Halli* from Anticosti is incrustated in precisely the same manner with what I take to be a species of *Stenopora*. Eichwald places his genus among the

Cystidea; but the more general characters, such as a jointed crinoidal column, the arms, or pinnulæ, and the peculiar orifices which characterise all true Cystideans, are not forthcoming. It is barely possible that his view may be the correct one.

The fossil called *Sphæronites tessellatus* (Phillips), from the English Devonian rocks has the surface covered with hexagonal plates, and resembles, in general aspect, a species of *Pasceolus*. Mr. Pengelly has figured a specimen in the *Geologist*, vol. iv, which shows the interior, covered with a net-work of vertical and horizontal ribs, giving the appearance of the inner surface of the specimen of *Receptaculites calciferus* above noticed. He proposes a new generic name, *Sphærospongia*, for it. If the specimen figured by him be truly of the same species as that described by Phillips, it would seem that an internal structure like that of *Receptaculites* is not inconsistent with an integument of hexagonal instead of quadrilateral plates. I do not see, however, how the net-work figured by Mr. Pengelly can be made to fit hexagonal plates in the way that the squares formed by the stolons of *Receptaculites* are adjusted.

M. M. Edwards and Haime have referred Eichwald's genus *Cyclocrinus* to the *Zoantharia*. Whether they are right or not with regard to the Russian species, I can most confidently assert that *Pasceolus* is not a coral. It may be allied to *Receptaculites*, but its true zoological position is quite undecided at present.

(To be continued.)

GOLD MINES AND GOLD MINING IN NOVA SCOTIA.

By HENRY F. PERLEY, Esq., Halifax, N. S.

As in other parts of the world where gold is now being produced, the discovery of the precious metal in Nova Scotia was made by accident. A man drinking at a small brook; a few specks of the shining metal found in the sands of the sea-shore; particles of gold in a piece of loose quartz,—first brought the auriferous character of the Tangier, the Wine-Harbor, and the Renfrew Gold-Districts into notice. In other localities, search was made among the quartz-boulders which had lain undisturbed and unnoticed for years, and they proving auriferous, led to the establishment of such localities into gold districts. It is somewhat strange that

the existence of these auriferous deposits should have remained so long undiscovered even by the road-maker or the agriculturist, and after the many scientific explorations of the country, which have been made during the present century, by men eminent in Geology and Mineralogy. Principal Dawson, in 1855, suggested the probability of the discovery of gold, and with some accuracy indicated the region in which it might possibly be found, but he made no search for it.

The first discovery of gold was made in the early part of the year 1860, on the Tangier River; and since that time, other localities have been discovered, nearly the whole of which are now being worked upon. During the excitement of first discovery, individuals fancied that fortunes were to be made speedily, by the aid of a shovel, a pick, a pan, and with the expenditure of but little capital. Mining-lots were laid off by the Government, fifty by twenty feet, for which high rentals were asked; and in one or more of these the miner, whether practical or amateur, expended his labor and his capital, and in the end all failed;—the practical man from the want of space on which to deposit the debris of his underground excavations; and the amateur, because his patience, his hopes of making a speedy fortune, and his capital, were all exhausted. Individual enterprise having thus proved unsuccessful, companies were formed; and the Government, seeing the absurdity of leasing such small areas, increased their size to 150 by 200 feet, and modified and improved the law relating to the Gold Fields. Even with these advantages, many companies failed or sold out to others; and now a large proportion of the mining areas in the province are held by companies raised and incorporated in Massachusetts and New York, having capitals ranging from \$100,000 to \$1,000,000. A number of these companies have proved to be stock-jobbing operations; speculators having taken advantage of an excitement created on the stock-markets of Boston and New York, to palm off unproductive and almost valueless properties; and to aid their operations, examinations and reports were made by able and scientific men brought for the purpose, who were capable of investigating thoroughly the geological phenomena and characteristics of the auriferous districts. It is to be regretted that their reports are only servicable to assist in the sale of stock, and add but little to the otherwise scanty information of the geology of the gold districts. The various companies at work have had indifferent success; a few are

carrying on operations and making a profit; whilst others barely pay expenses; but the whole are now suffering from a depreciation in the value of their stock, caused by the bursting of speculative bubbles thrown into the market, and wafted upwards by seductive scientific reports, by the exhibition of rich nuggets and massive bars of gold, and by wondrous tales of the yield to the ton of ore and of the expected profits. The question whether gold mining in Nova Scotia is a profitable and safe investment for capital, is still an unsettled one, though, judging from the past, it would appear to be both unsatisfactory and unprofitable.

The whole southern coast of Nova Scotia, from Cape Canso to Cape Sable, consists of altered or metamorphic rocks, such as slates, quartz-rock, gneiss, &c. This zone averages about thirty miles in width, and in it are found the gold-bearing quartz-veins for which Nova Scotia has now become noted, and from which a large amount of wealth is being derived. The aspect of the country is barren and sterile, the hills in many places being covered with a sparse and stunted growth of trees; huge boulders of granite, quartzite, or conglomerate abound, giving to the district under consideration the appearance of a country entirely unsuitable for agriculture. Prof. Dawson, in his 'Acadian Geology,' page 364, in treating on the Metamorphic district of the Atlantic coast, states, "With respect to the surface and industrial capabilities, the different rocks occurring in this district present very various aspects. The clay-slate often has a regular undulating surface and a considerable depth of shingley or clay soil of a fair quality, though usually deficient in lime. These slate-districts, however, contain beds of quartz-rock, which form rocky ridges, from which boulders have been scattered abroad, and which, by damming-up the surface waters, produce lakes and bogs, an effect also produced by the ridged structure of the slate itself, and the impervious sub-soil which it affords. Wherever, as for instance in North Queens and Lunenburg, the slate is sufficiently elevated for drainage, and not encumbered with surface stones, it supports fine forests and valuable farms. Where quartz-rock prevails, the soil is almost invariably extremely stony and barren. Instances of this occur in Southern Queens, near Halifax, and in the hills near St. Mary's River."

With regard to the position of this metamorphic band in the geologic scale, some doubt seems to exist. There is no positive evidence of its geologic age—no trace of a fossil has been found in

any of the slates or associated rocks.* Prof. Dawson favors the belief that they are metamorphic Lower Silurian rocks. It is evident to the observer that they are highly metamorphic, as well as changed from the horizontal position they once occupied, by upheavals which have thrown them into positions almost vertical; and that at the time of upheaval the innumerable quartz-veins which are now known to exist, must have been formed.

The general character of the geology of the district may be stated in a few words. It consists of thick bands of slate and quartzite, having a general east and west strike, and highly inclined. In several places, masses of granite project through these rocks, and in their vicinity the quartz-rock and clay-slate are usually replaced by gneiss and mica-slate, or other rocks more highly metamorphosed than usual. The general dip of the strata is about 60° , but it ranges in localities from the vertical to the horizontal. From the examinations of Mr. Campbell of Halifax, it was found that the strata in the metamorphic district have been folded or plicated no less than six times, and that the summits of the folds or the anticlinal axes thus formed, were denuded or abraded during the drift or glacial period. To quote from a report made by Mr. Campbell to the Provincial Government: "In all vertical sections hitherto made out across the rocks of the south or Atlantic coast of the Province, but one line of elevation, or anticlinal axis, is represented along the centre of a band of strata over thirty miles in breadth.† If this had, in reality, been the stratigraphical arrangement in the south coast-band, there would exist but a poor chance of many of its older strata being brought to the surface in lines of upheaval along the north coast of the Province, where so great an accumulation of newer schistose and Carboniferous rocks has taken place; for such an arrangement as one line of elevation in such a broad band of strata, would necessarily imply a vertical thickness of at least ten miles of beds.

"As it is, however, scarcely two miles in vertical thickness, the beds are brought in section to the surface, for they are brought up in six different lines of elevation or anticlinal axes, instead of one.

"By referring to the section attached [to the Report] it will

* Dr. Honeyman has recently announced the discovery of fossils supposed by him to be primordial; but they have not been described.—EDS.

† This is scarcely correct; though no attempt had previously been made to work out the details of the numerous folds or dislocations.—EDS.

be observed that the clay-state is superimposed on the quartzite as a distinct group, and not interstratified with it.

“The line on which this section is made extends from the Atlantic, at the south-east entrance of Halifax Harbor, to the Renfrew Gold-Fields, a distance of a little over thirty miles, intersecting the anticlinals mentioned. These anticlinals run nearly parallel with each other from the extreme western coast of the province to the sea-shore between Cape Canso and Liscomb Harbor. This gives them a curve, from the strike altering from east and west to south 60° east, and to the westward of Halifax, to the south-westward. They do not lie at equal distances apart, owing no doubt to the strata being folded up irregularly with different angles of dip.”

That Nova Scotia has been subjected to glacial action, and that during the period of that action the summits of these anticlinals were denuded and swept away, is plainly apparent. Where the rock is exposed, whether by the removal of the boulder-clay or otherwise, it will almost invariably be found to have a smooth polished surface, and to be marked with furrows, scratches, and striae, all of which must have been formed by the passage of heavy and hard substances over it. These scratches indicate the direction in which the moving masses passed over, and they are found to have a south-eastern direction over the whole province, modified of course by local circumstances.

The fact that this denudation has taken place, and the non-discovery of rich alluvial washings, have led to the belief that the major portion of the drift has been carried away and deposited in the Atlantic Ocean, forming the submarine banks which skirt the southern shore of the Province. This belief is further strengthened by the fact that gold is largely disseminated through the sands of Sable Island; this being the only point of those banks raised above the sea, and at the same time lying in the general direction of the drift.

Mr. Campbell does not suppose that the abrading force was sufficient to expose the whole of the quartz-veins on the strata, but that many exist which have a capping on the summits of the anticlinals. Where the veins are exposed in these abraded surfaces, they are found to dip to the north or south, as they lie to the north or south of the anticlinals. Thus, at Waverley, which is situated on the fourth anticlinal axis, the veins which have been opened are found all to dip to the north, proving them to be on the north side

of the anticlinal; while at Oldham, which is on the fifth axis, the veins are found dipping both to the north and south, which leads to the belief they lie on either side of the axis.

The rock most noticed in the mining districts is the quartzite—commonly called 'whin' by the miners. It is a strong compact rock of a grey color, consisting of finely granular quartz. It is supposed to be of immense thickness, for, according to Mr. Campbell, where it lies exposed to view in the cuttings of the railway from Halifax to Truro, and where measurements were made, it was found to be over one mile in depth.

The slate-rock which usually accompanies all the gold-bearing quartz-veins, is generally argillaceous; and, according to the authority of Prof. B. Silliman, not an example of talcose slate appears. His examinations only extended to the eastern portion of the Province, and if it does exist, it seems to have escaped his notice. Mr. Poole, who reported to the Provincial Government in 1862, on an examination which he made of the metamorphic district west of Halifax, states that he found talcose slate at La Have River and Ritchie's Cove, and talcose slate with pyrites in quartz at the Cream Pots. Near Cranberry Head, in the county of Yarmouth, chloritic slate exists; pure chlorite, and quartz intimately coated with minute crystals of chlorite, are found abundantly at Tangier. The slates are generally found forming the lower or foot wall of the quartz-veins, whilst the hanging or upper wall is usually quartzite. In some instances both walls are of slate; but that both are of quartzite is of very rare occurrence. Sometimes it is found that a vein is split into two, by a third and narrow vein, having thin walls or partings of slate.

The associated minerals found are zinc, blende, iron pyrites, mispickel or arsenical pyrites, galena, and the yellow sulphuret of copper.

Both iron pyrites and mispickel are found in the quartz-slates and quartzite indifferently; and with the mispickel, gold is almost invariably associated, particularly at Montague, where large quantities of this mineral are found, in which gold may be plainly observed; indeed a lump can hardly be broken up without exposing to view particles of gold. Galena is found in small quantities, and some specimens have gold in admixture with it. Blende is found intimately mixed with the quartz, and sometimes lying on the quartzite at its junction with the quartz. Its presence is accepted as a good sign by the miners. The pyrites is often found

decomposed, and converted into peroxide of iron, and, by discoloring the adjacent rocks, often marks the outcropping of a vein.

The question may however be asked, are the veins of quartz in Nova Scotia true veins, or beds? Up to the present time no decision has been arrived at in reference to this subject; and it is to be regretted that the gentlemen who, during the past year, have visited the gold-fields to examine them geologically, have not made known their views on this point. That the quartz is found following the planes of cleavage is apparent; but whether the plane of cleavage is the true bedding of the slate, is not yet fully settled. *If the dip and plane of cleavage are identical, then the veins of quartz must be termed true beds or strata; but if the dip and plane of cleavage do not coincide, then the quartz occurs in veins.* A solution of this point can easily be accomplished, and will be of interest to the geological student.

The quartz-veins of Nova Scotia vary in width from one eighth of an inch to eight feet, though the general width is found to range from three to twenty inches. Experience has shown that the larger the veins, the poorer their yield in gold. On the property of the Waverley Gold-Mining Company at Waverley, there are three veins respectively, twenty-four and thirty and thirty-six inches in width, which are barren; while in their neighborhood, veins of from six to eighteen inches produce from thirteen to twenty penny-weights of gold to the ton of quartz. In the larger veins the quartz appears to be free from the foreign minerals already mentioned, of a milk-white color, very much laminated, and breaks into irregular masses; while the productive quartz varies in color, is pure and crystalline, breaks into more regular forms, and is intimately mixed with the minerals above alluded to.

Gold is not however entirely confined to the quartz-veins, but is often found mixed with the slates on the foot-walls, and in the partings in several veins. But whether it is found in the quartz, in the metallic sulphurets, or in the slates, it is always pure, and, where visible, is seen in the form of grains or nuggets, called 'sights' by the miners. In some cases, however, it is invisible to the eye, and can only be separated by crushing and amalgamation. It has been observed, that where a very large sight, or quantity of sights, is found, which would indicate increased richness in the vein, it most generally follows that for some distance or depth on either side of the rich spot the vein is almost barren.

Veins do not preserve their width as they descend: they are

found to vary greatly, sometimes gradually thinning out to a mere thread, and then increasing in size as a greater depth is reached. They are often split-up into two or more branches, or are greatly enlarged by the junction of cross-veins. Neither do the veins dip with any degree of regularity, many of them having three or four rates of dip, which renders the sinking of shafts a troublesome and oftentimes an expensive matter; for the shafts are sunk vertically through the earth to the bed-rock, and then generally driven with the vein, and always on the lower or foot-wall side. Faults occur in most veins, owing no doubt to dislocations of the strata; and instances are known where the vein has been cut entirely off, and thrown for some feet.

It is generally supposed that auriferous veins present the richest ore at the surface, and decrease in the value of their yield with the depth, until at depths ranging from one to two hundred feet they no longer pay for working. This opinion is countenanced by the highest French and English authorities, and is supported by a wide class of facts. In Australia very large sums were spent in deep sinking on veins which were productive at the surface, but when certain depths were reached they proved barren and unprofitable.

In 1859 and 1860, after the quartz veins of Victoria (Australia) had been for some time neglected, the received opinion that auriferous veins diminished in value with their depth was disregarded, and, judging from a few exceptional cases where veins had paid at depths of from two to four hundred feet, those veins that had proved rich at the surface or within a depth of one hundred feet, were again opened and active operations carried on. But it was found that the rule held good; and it is boldly stated, that there are not six veins in the colony of Victoria (in 1860) from which a sufficient quantity of gold had been extracted at a depth of four hundred feet to pay the cost of extraction. Sir Roderick Murchison has stated, that the rule prevails in auriferous countries "that the working of gold-bearing quartz is not remunerative excepting near the surface, the ore being concentrated in the upper parts of the lodes."

Whether this rule will hold good in Nova Scotia still remains to be proved. So far, varied success has been met with in different shafts, which have been sunk to depths reaching from eighty to one hundred feet. At Waverley a shaft is now down one hundred and eighty-five feet, and the quartz obtained at that depth proves richer than that obtained at or near the surface.

A fact respecting the distribution of gold in the vein-rock, has been established in the mines of Nova Scotia: it is, that the precious metal does not pervade the whole vein alike, but runs in bands or streaks, at different rates of dip or inclination, in different veins. Were this fact fully understood, miners would be enabled to calculate, from observations and measurements made in openings on the vein which they propose to mine, at what depth they may expect to reach the auriferous and paying portion of the vein in new shafts. The following extract from Hittell's "Resources of California" is in elucidation of this fact:—

"Most of the gold in a lode is usually in a rich streak near the foot-wall or lower side, as if the metal had settled down by its gravity. The rock near the hanging-wall or upper side of the lode is the poorest. Occasionally several rich streaks will be found in a lode—one streak with coarse particles, another with fine. All parts of a lode are not equally rich; but the gold is found in spots. A lode which is very rich in one place, may be poor in another not very far off; indeed, there is no auriferous vein in the state known to be rich for a long distance on the surface. The gold is found in streaks or *pockets*; the rich streak runs downward, or has a dip in the lode. It is a matter of very great importance to the miner to ascertain the direction of this dip, and here is the rule: Take out some of the vein-stone, and examine the wall-rock carefully. In most veins it will be found that the wall has little furrows, as though the lode had been pushed upwards. These furrows indicate the direction of the dip of the rich streaks. Pockets may be considered as interrupted streaks; and when one rich pocket is discovered, others may usually be found by going down into the vein in the proper direction, and that is ascertained in the same manner as for continuous streaks."

Among all the veins of quartz discovered, none has excited so much curiosity, or given rise to so much speculation on the theory of its formation, as the horizontally plicated or folded vein found on Laidlaw's hill in the Waverley district.*

The following description of this vein by J. Arthur Phillips, of London, will convey some idea as to the appearance of this peculiar vein:—

"The most remarkable deposit of auriferous quartz hitherto

* See a description and figures of them by Prof. Silliman in Silliman's Journal [2], xxxviii, 104.

found is undoubtedly that of Laidlaw's farm. The principal workings are situated near the summit of a hill composed of hard metamorphic shales, where openings have been made to the depth of from four to five feet upon a nearly horizontal bed of corrugated quartz of from eight to ten inches in thickness. This auriferous deposit is entirely different from anything I had before seen, and, when laid open, presents the appearance of trees or logs of wood laid together side by side, after the manner of an American corduroy road. From this circumstance the miners have applied the name of 'barrel-quartz' to the formation, which in many cases presents an appearance not unlike a series of small casks laid together side by side and end to end."

"The rock covering this remarkable horizontal vein is exceedingly hard; but beneath it for some little distance it is softer, and somewhat more fissile. The quartz itself is foliated parallel to the lines of curvature, and exhibits a tendency to break in accordance with these striæ."

"The headings, and particularly the upper surface of the corrugations, are generally covered by a thin bark-like coating of brown oxide of iron, which is frequently seen to enclose numerous particles of coarse gold, and the quartz in the vicinity of this oxide of iron is itself often highly auriferous."

Up to the present time this vein has not been found further to the eastward than the point of its first discovery, whilst it has been traced some eight hundred feet to the west, in all cases being overlaid with rock, and that again with earth, in some places to the depth of ten feet. Under the impression that the stratum in this locality either lay in its original horizontal plane of deposition, and had not been subjected to upheaval; or that after being uplifted it had become folded over into the position it occupies; or that it is the summit of an anticlinal axis; it was judged that other and parallel veins would be found at lower depths, underlying the vein exposed. Shafts were sunk to depths of over fifty feet, and exploring drifts run out at that depth, but without success; and it is doubted whether any other veins do exist. This is all the more singular when it is stated, that on the opposite side of Lake Thomas, a distance of only one quarter of a mile to the westward, the strata are upheaved at an angle of 80° and numerous veins of quartz are found, and afford profitable returns on being worked.

The discovery of gold in the conglomerate at Gay's River has

given rise to much speculation as to its origin in that matrix. The following description has been extracted from a letter from Mr. C. Fred. Hartt, to Principal Dawson, on this subject, a copy of which has been kindly furnished by Mr. Hartt:—

“ At Corbett’s Mills the clay-slates are overlaid unconformably by nearly horizontal beds of grey and red conglomerate grit, and sandstone of the Lower Carboniferous, probably of the age of the lower coal-measures. These are overlaid by a mass of drift of variable thickness, and beds of stratified sand and clay. These conglomerates are not Silurian, for they overlie unconformably the rocks of that age, and they are totally unlike any Devonian rocks occurring in the Province. Lying as they do on the margin of the Carboniferous basin, they agree perfectly with the conglomerates and sandstones of the Lower Carboniferous group, for they contain a few ill-preserved fossil-plants like those found in similar Carboniferous beds.

“ The under part of the bed of the conglomerate or grit, at its junction with the slates, is highly auriferous, the gold occurring principally in the form of flattened scales, sometimes a quarter of an inch in diameter, disseminated through the rock. Many fragments of conglomerate have been found, not a cubic inch in size, on the surfaces of which from twenty to thirty of the scales could be observed with the naked eye. In the workings now being carried on, levels are driven into the bank at the junction of the two formations; a foot or more of the under part of the conglomerate bed is removed, and washed in the common miner’s cradle and pan, and yields rich returns. Only one vein of quartz, one quarter of an inch in thickness, has as yet been discovered in the slates under the Carboniferous beds; it is highly auriferous, and has a strike of about north and south, and dips to the eastward about 70°.”

No alluvial washings to any extent exist in the Province at the present time. In 1861, the discovery of gold in the sands of the sea-beaches of the peninsula known as the Ovens, in the County of Lunenburg, created great excitement for a time; but this subsided as the returns gradually grew poorer, and by the end of the summer of that year the washings were exhausted. The gold found is not to be ascribed to deposition during the drift-period, but is probably derived from the cliffs which form the shores. These cliffs are about fifty feet in height, and are composed of bands of hard and soft laminated slates, with veins of auriferous

quartz, and bands of common and arsenical pyrites intermixed. The action of the elements in decomposing the pyrites, the effects of the sea-waves in crumbling the soft slates, together with the frosts of each succeeding year, all have a tendency to undermine and destroy the coast; and the debris thus formed is washed away during heavy gales, and, after a lapse of time, again appears in the shape of sand and gravel, together with the smaller and lighter particles of gold which have been released from their matrices.

During the present year applications have been made to the Gold Commissioner for areas on the Middle River, in Victoria County, Cape Breton, and after due examination it was proclaimed a gold district. Up to the present time all the gold produced is from alluvial washings, and it is spoken of as being 'coarse and nuggetty.' Very little is now being done in the district, and the excitement has died away.

To obtain the gold contained in the gangue the following processes are necessary, viz., calcination, crushing, amalgamation, retorting, and smelting. Many omit the first operation, but all the others are indispensable. A difference of opinion exists as to the benefit of calcination, some contending that the wear and tear of machinery in crushing 'raw' and unburnt quartz are equal to the cost of calcination. Quartz is either calcined by being piled into heaps in alternate layers of quartz and wood; or is placed in the same manner in kilns constructed for the purpose, each kiln holding from ten to fifty tons. The whole is thus submitted to the action of intense heat, the greater portion of the sulphur and arsenic components of the pyrites are volatilized, and the quartz itself is rendered friable, and easier to crush in the mills. It is affirmed that quartz thus calcined will give a larger yield per ton than the unburned quartz. The sulphur and arsenic being in a great measure driven off, the quicksilver amalgamates with the gold released from the sulphurets. On the other hand, it is affirmed, that the cost of fuel and transport to and from the kilns, and the interest on the cost of these, all amount to a larger sum than the presumed loss in gold, *plus* the wear and tear of the machinery. The method of calcination in use in Nova Scotia does not fully answer the purpose for which it is intended, viz., the decomposition of the sulphurets. The quartz as it is extracted from the vein, is thrown into the kilns, without being broken into small pieces so as to expose the pyrites contained in the interior of the masses; and it is therefore impossible that the

intended effect can be produced. Although the auriferous ores of Nova Scotia may be deemed pyritous, yet they are comparatively free when contrasted with the ores of Colorado. These are highly pyritous, and calcination or desulphurization is now being carried on to a great extent. In the process known as Keith's, the ores are first crushed to a fine powder, and then submitted to the action of fire by being drawn through a flue, and are deposited in chambers at the other end. By actual trial, one cord (128 cubic feet) of ore, weighing 14,700 lbs. weighed only 8871 lbs. after being submitted to this process; having lost 5829 lbs., which had passed away in vapor. That the yield of gold was increased may be learned from the fact that a cord of ore treated by the old process yielded at the rate of \$100 per cord, whereas after being desulphurized the yield was \$864,—nearly a ninefold increase.*

The quartz is brought from the kilns to the mill, and is there broken up into small pieces, either by hand or by means of a *cracker*. This machine consists of a heavy-recessed cast-iron bed-plate; two sides of the recess (which is about twelve inches deep) are vertical, and the other two are inclined towards each other. On the sloping faces are secured corrugated plates of cast iron. In the recess, working on a pin in its lower end, is a heavy iron block having corrugated plates on two faces. This block works backwards and forwards in the recess, and the quartz, being fed between the plates, is gradually crushed up, and falls out at the bottom. By the use of this machine a large quantity of quartz can be crushed in a day, better than it can be done by hand, and at a cheaper rate.

After being cracked, the quartz is submitted to the operation of crushing, two modes of which are in operation in the Province, viz., by stamps, and by Chilian mills. The stamps are of two kinds, square and revolving. In either case a *battery* consists of a box, which may be made of cast or wrought iron, or of wood faced with boiler-plate; the bottoms of both kinds being made of cast iron, and protected by small plates called *anvil-blocks*. In the *stamper-box* are placed either four or six stamps; a stamp

* The process here referred to as Keith's appears to be an imperfect form of that employed in the novel and ingenious methods of Messrs. Whelpley and Storer, of Boston, which seem destined to revolutionize the art of metallurgy. See, for a brief notice of them, Silliman's Journal [2], xxxvii, 401.—Eds.

consisting of a head, shoe, and rod, each stamp weighing from 350 to 700 pounds. The shoes are made of hard grey iron to withstand the wear, and they are replaced in the bottom of the head when worn out. The stamper-rods are firmly held by guides, and carry projecting pins or collars. A cam shaft, carrying as many cams as there are stamps, is worked by any motive power, and in its revolutions the cams are brought into contact with the pins or collars, and the stamps lifted and dropped in rotation. The difference between the square and revolving stamps is, that the heads of the square stamps are square, and their united areas are almost equal to the inside area of the stamp-box, and they merely rise and fall without any other motion. The revolving stamps have round heads and rods, and by the action of the cam on the collar as the stamps are lifted, a circular motion is given, which, continuing through the fall, is supposed to be more effective in crushing the quartz to a fine state, than the simple lift and fall of the square stamp.

The quartz is fed into the rear of the box in small quantities at a time, and it is there acted upon by the stamps. A constant supply of water, generally hot, to assist the amalgamation, is led into the boxes, and forms a paste with the crushed quartz. In front of the boxes is an oblong opening, which is covered with a wire-net, having from 160 to 200 holes to the square inch, and through this the whole of the crushed quartz must pass.

The Chilian mill, an improvement on the Spanish *arastra*, still in use in South America, consists of a bed about six feet in diameter, which may be either of cast iron or of some hard solid stone, surrounded by a sloping rim of stout sheet iron. On this bed, two edge-wheels revolve, and, as the quartz is fed under them, it is crushed and mixed with the water supplied into a thin paste. A constant supply of water is kept up, and the overflow carries away the siliceous particles which are held in suspension. Several of Howell's rotary crushers have been tried, but the whole have proved failures, and are laid aside.

The extraction of the gold from the paste is effected by means of quicksilver, and is termed amalgamation. There are many different appliances for producing this result in operation in the Province. A description of all the modes would occupy too much time; and it may therefore suffice to say, that in the Chilian mill the quicksilver is placed in the pan, and is brought into contact with the gold as it is separated from the quartz by the act of

crushing. In the stamps, a portion of quicksilver is placed in the stamper-box, and the paste, as it flows forth, is carried over plates of copper amalgamated with quicksilver; or is led directly into shaking-tables; passed over riffles, having mercury in the top riffles; over complex arrangements of copper cups containing mercury; through amalgamated pans, &c.; or combinations of two or more of these systems. In some mills, after the paste has passed through or over the amalgamating system, it is passed through a Chilian mill to recover any gold that may have passed away in the tailings. In others the tailings are carried over inclined tables covered with blankets, in the asperities of which the metals lodge by their gravity, while the silicious particles are washed away. These blankets are removed at intervals, washed of their contents, and then relaid. Or the tailings may be passed over a buddle, and the metallic portion thus collected. In either case, this is placed in barrels attached to a horizontal shaft, with a few pounds of mercury and a quantity of water, and the whole kept revolving for a number of hours. The yield of gold in this process is, however, generally very small. The tailings are then allowed to go to waste; the propriety of doing which, will be alluded to hereafter.

The question, can there be perfect amalgamation? is still unanswered. Many machines, simple or complex in their construction and arrangement, have been invented, each of which has been deemed the only perfect machine, and yet none is perfect. An arrangement by which the quartz crushed to a fine powder and freed from the sulphurets could be passed through a body of mercury so as to ensure contact with every particle of gold contained in the mass, and at the same time to avoid the loss of mercury, would be the best for amalgamation. A number of machines to effect this have been constructed, but have not proved successful. The great difference between the specific gravities of quartz, 2.60, and mercury, 13.5, renders it a difficult matter to pass successfully the lighter bodies through the denser.

That a large portion of the gold from the mines of Nova Scotia is lost and carried away in the tailings is well established; and with the systems of amalgamation in use, it would appear impossible to avoid a loss. In the Chilian mill the gold is ground to a fine powder, and may be seen floating on the surface of the water. Although its specific gravity is so great, no known means will cause it to settle, and it is carried away in the overflow. Under the stamps the quartz is crushed into fine particles, and adhering to

many of these may be observed, by the aid of a glass, minute specks of gold; these of course are washed away. Again, gold is intimately associated with the sulphurets, and is lost as the pyritous grains are swept away with the silicious particles; and even grains of gold are carried away by too copious a supply of water. At Lunenburg where the gold was washed out of the sands of the sea beach, great difficulty was experienced in obtaining amalgamation, owing to the particles of gold being covered with a film which entirely prevented a union with mercury. No doubt this coating was formed by the decayed organic matter brought by the waves.

Allusion has been made heretofore to the loss of gold by reason of a non-reduction of the sulphurets; and in elucidation of this point, the following assays were made on tailings taken from a mill at Waverly.

Assay No. 1; tailings selected from different parts of the tailings-bank. 100 grains showed a yield equivalent to 6 dwts. 8 grains of gold to the ton of 2000 lbs.

Assay No. 2. From 5 lbs. of tailings all the silicious particles were washed out, leaving the sulphurets, which only amounted to 3 oz. 11 dwts. 100 grains, and showed a result of 6 oz. 14 dwts. 1 gr. of gold, and 10 dwts. of silver, to the ton of 2000 lbs.

Assay No. 3; tailings as they were taken from the bed and reduced to a fine powder. 100 grains yielded the equivalent of 7 dwts. 16 grs. of gold, and 2 dwts. 14 grs. of silver, to the ton of 2000 pounds.

In considering the results of these assays, it is apparent that a great loss takes place in permitting the sulphurets to flow away. By assay No. 2 the sulphurets amounted to 3 oz. 11 dwts., being $\frac{1}{17}$ or 5.88 per cent of the mass, and the result of the assay showed an amount equal to 6 oz 14 dwts. 1 gr. of gold and 10 dwts. of silver per ton of 2000 lbs. Allowing the market value of gold to be \$19.75 per ounce, the value of a ton of sulphurets, setting aside the value of the silver in this instance, will be \$132.36. As it takes seventeen tons of tailings to produce one ton of sulphurets, it follows that each ton of tailings is worth \$7.78. By assay No. 3, the yield from the tailings taken as found, but triturated to a fine powder, is equal to 7 dwts. 16. grs. to the ton; this at \$19.75 per ounce, amounts to \$7.59. By assay No. 2 the value of a ton of tailings is shown to be \$7.78,—the two results closely agreeing.

The mispickel from Montague was analyzed for Prof. Silliman at

Yale College. It was first crushed, and sifted to separate the coarse gold, after which that portion which was finely disseminated was separated by roasting, fluxing, and cupellation. The results calculated for 2000 lbs. gave of coarse gold 0.5676, and of the diffused gold 0.2740; = 0.9419 lbs., or 13 oz. 12 dwts. 22. grs. of gold to the ton of mispickel. This gold contained only 3.34 per cent of silver.

The separation of the gold from the sulphurets must be a chemical process, and it is a question whether the cost of extraction may not exceed the value of the gold obtained. In the gold mines of Virginia and North Carolina, the surface of the tailings-bank is plowed over, and the sulphurets are thus exposed to the action of the weather; when a sufficient time has elapsed, the surface tailings are run through the mill. This is always found to pay expenses, and leave a profit. During the month of August the agent of the Chebucto Company of Waverley treated a quantity of tailings in this manner, and was surprised to find that the results would pay all expenses, and leave a balance.

After the lot of quartz has been crushed, the mill cleaned-up, and the whole of the mercury used is washed free from all silicious particles and sulphurets, it is the custom with some to allow the mercury to stand for some hours, when the amalgam settles to the bottom, and the free mercury can be poured off for future use; or the whole quantity may be subjected to pressure in chamois leather, when the superfluous mercury is forced out through the pores of the leather, leaving the amalgam in the shape of a silvery pasty mass; but whichever means may be adopted, a certain quantity of dissolved gold passes away with the mercury, which, it is said, is beneficial in promoting amalgamation in future operations.

The separation of the gold from the mercury is performed in the operation of *retorting*. The retort is a cast iron vessel, conical in shape, having a cover which is made to fit extremely tight, to prevent the escape of the fumes of the mercury. In the cover is inserted a bent iron tube. The amalgam is placed in the retort, the cover securely fastened down, and the whole apparatus placed in the fire and covered with fuel. So soon as the mercury begins to distill over, the end of the tube is plunged into cold water, and a small stream of water is allowed to fall on the tube itself; when the mercurial vapor condenses and assumes its original form. Heat must be kept up until all the mercury has passed over, when the

retort is removed from the fire, and, after being sufficiently cooled, is opened, and the gold removed. Great care must be taken in retorting, otherwise a loss of gold may take place, either by being partially melted and made to adhere firmly to the sides of the retort; or in case of too great a heat being applied at an early stage of the operation, the mercury is flashed as it were into vapor, and fine particles of gold are sprinkled and deposited over the inside of the retort, and even into the interior of the tube. Where the amalgam has been carefully cleaned, and care has been taken in retorting, the gold is obtained in one lump, having the shape of the bottom of the retort, and is of a clear bright yellow color; otherwise, it is dull and dirty looking, and may be seen sprinkled with grains of quartz and pyrites. Retorted gold is porous and spongy in appearance, and will occupy a much larger bulk than the same weight of smelted gold. It is often remitted by the agents of different companies in this state, but does not command the same price as smelted gold. In all returns made to the Provincial Government retorted or unsmelted gold is valued at \$18.50 per ounce, and smelted gold at \$19.50. Gold in bar commands a price in the market of from \$19.75 to \$19.80 per ounce. Retorted gold generally loses in weight by smelting, owing to the oxidation of any of the baser metals which may be alloyed with it; and by the total expulsion of the mercury used in amalgamation, a notable quantity of which oftentimes remains with the gold, when the retort has not been sufficiently heated.

It is to be regretted that the law for the management of the Gold Fields, does not extend to the establishment of a Government Assay Office, where gold could be smelted, its fineness determined, and the bar officially stamped. By this means all gold would bring a price equivalent to its fineness, and the purchaser be protected from fraud and imposition.

The Gold Districts proclaimed in Nova Scotia are eleven in number, viz: Wagamatcook in Cape Breton, Stormont, Wine Harbor, Sherbrooke, Tangier, Lawrencetown, Montague, Waverly, Oldham, Renfrew, and the Ovens at Lunenburg. Mining is being carried on to a small extent at Gay's River, on private lands

These districts are now the property of the Crown, all private rights having been re-vested; and areas, or lots measuring 250 feet by 150 feet have been laid off; the smaller dimension being on the strike of the veins. Areas may be taken up, by application

to the Chief Commissioner of Mines, or to the Deputy Commissioner resident in the district, and secured by the payment of two dollars, when a lease will be granted for a term of twenty-one years. Where gold is discovered on private lands, as at Gay's River, and the Government decline to re-vest the land, applicants for areas must first arrange with the proprietor of the land, in writing, for leave to enter and work, and, on the agreement being deposited with the Chief or the Deputy Commissioner, a lease will be issued.

By the covenants in the lease, the lessee must perform each year one hundred days' labor in each area; but, if he holds ten, and less than twenty, he will not be required to perform during the first year more than three fourths of the days' labor above required; if holding twenty or more, but less than thirty areas—only one half of the days' labor will be required; and if holding thirty or more, only one quarter of the amount. The lessee must also on the first days of January, April, July, and October, make a return to the Commissioner showing the number of days' labor expended, and the number of tons of quartz raised during the preceding quarter. If quartz has been sold, all details must be given. He must show the weight of all quartz sent to a mill; the name of the mill; the yield of gold; and also a statement of all gold which may be obtained in other ways than in a mill,—as, for instance, from alluvial washings, or by crushing by hand.

Lessees of areas, or parties not holding areas, wishing to erect a crushing-mill, must obtain a license to work such mill, and enter into bonds in the penalty of two thousand dollars for the payment of all royalty due the crown on gold obtained in the mill, and for a true and exact account of all quartz crushed, where from, by whom owned, the yield of gold, whether unsmelted or smelted; and the amount of royalty due the crown, which amounts to three per cent. on the value of the gold obtained; unsmelted gold being valued at \$18.50, and smelted at \$19.50 per ounce. These returns must be made monthly, and sworn to, and the royalty due paid over.

Although the owner of a mill may not be the owner of the quartz crushed in his mill, he alone is responsible for the royalty, and for making the returns; on neglect or refusal to do which, the mill-license can be cancelled, and the bondsmen proceeded against in the Supreme Court for the recovery of any royalty which may be due.

In September of the present year, ninety-five mines were being

worked, giving employment to eight hundred and thirty-six laborers. Thirty-four crushing-mills were in operation, twenty-two of which are driven by steam power, and the remainder, or twelve, by water. The average wages paid will be about one dollar per day; but very many of the miners, particularly those from Great Britain, take contracts for sinking shafts, driving adits and drifts, and for getting out the quartz. Where quartz is crushed at a mill, the cost per ton for so doing varies from two to three and a half dollars.

The yield from all the mines for the year 1862 was 7,275 ounces; for the year 1863, 14,001 ounces; and for the three quarters ending October 1st, 1864, 14,565 ounces; making a total of 35,841 ounces, as the result of two years and three quarters' mining. Estimating this at \$19.00 per ounce (for the greater portion is unsmelted gold), the value will be \$680,979.

Assuming the return for the month of September 1864 as a fair exponent of the yields from the different districts, it will be found that, if ranked according to the yield per ton, they will stand in the following order:

	oz.	dwt.	grs.
Montague	2	9	17
Sherbrooke	1	8	10
Tangier	1	5	13
Renfrew	1	4	18
Stormont (Isaac's Harbor).....	1	2	12
Wine Harbor	1	2	2
Waverley	0	18	6
Oldham	0	15	20

If ranked according to the total yield of gold during the month, they will stand thus:

	oz.	dwt.	grs.
Waverley	855	3	3
Sherbrooke	378	6	1
Wine Harbor	220	10	15
Oldham	176	2	1
Montague	134	4	10
Renfrew	111	19	0
Stormont (Isaac's Harbor).....	99	17	6
Tangier	88	5	1
Other and unproclaimed Districts	10	4	3

Although the mines are worked, and the yield is annually increasing, still it may be doubted whether they are profitable fields for the investment of capital. An individual fortunate in

the possession of a single area, often reaps a rich return; while a company having a large working capital, and owning a large number of areas, will be unfortunate in obtaining results. Faults may occur in the veins, the rich streak may be passed through, and the vein becomes barren, or gradually thins out to a mere thread, in sinking upon it; the expense of sinking shafts and making adits, &c., in the hard rock; the cost of transporting the quartz to the mill, etc., all increase the expenditure, and the quartz obtained may thus not pay the cost of mining and crushing. A thin vein may produce a very large yield, and yet be unprofitable to work; while a thick and easily worked vein, though producing a low yield per ton, is often found profitable.

The following statement has been prepared from the return of the Chief Commissioner of Mines for the months of July, August, and September, 1864, and is intended to show the yield of the different districts per man employed. The return for the month of September has been used; the price of gold has been assumed to be \$19.00 per ounce, and the cost of crushing per ton to be \$2.50.

District.	Men employed.	Tons crushed.	Yield in ounces.	Value at \$19.00.	Crushing at \$2.50.	Yield per man.
Stormont.....	102	53	99	\$1881 00	\$132 50	\$17 14
Wine Harbor...	75	200	220	4180 00	500 00	49 00
Sherbrooke.....	107	266	378	7182 00	665 00	24 48
Tangier.....	59	69	88	1672 00	172 50	25 41
Montagu.....	45	54	134	2546 00	135 00	53 50
Waverley.....	278	937	855	16245 00	2342 50	50 00
Oldham.....	80	222	176	3344 00	555 00	34 86
Renfrew.....	40	91	112	2128 00	227 50	47 50
Total.....	786	1892	2062	39178 00	4756 00	43 94

In the above, deduction should be made to meet expenses of management, royalty, tools, machinery, &c.

The writer, not professing to be a geologist, has to acknowledge that he has drawn largely from Dr. Dawson's 'Acadian Geology,' and from the reports made to the Provincial Government, for much of the geological description contained in this paper.

[Accompanying this interesting communication was a collection of minerals from the gold-region of Nova Scotia, kindly presented by Mr. Perley to the Society. Maps and sections illustrating the paper, were also sent.]—*Communicated by the Natural History Society of New Brunswick.*

ON THE EXTRACTION OF COPPER FROM ITS ORES
IN THE HUMID WAY.

By THOMAS MACFARLANE.

In the last Report of the Geological Survey of Canada reference was made to the poor pyritous copper ores of the Eastern Townships; and with regard to the best method of utilizing them, it was remarked as follows: "It is much to be desired that some of the various methods which have been proposed for removing the copper in a soluble form, could be applied to these ores."* The importance of this question has by no means diminished, since the publication of the report alluded to. The recent discovery, in the neighborhood of Lennoxville, of several very promising beds of pyritiferous copper ore, the difficulty of concentrating these by any of the usual mechanical processes of ore-dressing, and the obstacles to the establishment of smelting-houses near to the mines for the production of ingot copper, all combine to render this subject one of somewhat more than ordinary interest.

The processes which have been from time to time proposed, and put into practical operation, for the humid treatment of copper ores are so numerous and diverse, that I shall not attempt to describe them minutely. I shall merely refer to some of the more important among them, and especially to those which bear some resemblance in principle to the method pursued in certain experiments which I have performed on a small scale, with various Canadian ores, in order to the extraction of the copper contained in them. The results of these experiments having been very satisfactory, I shall proceed to describe them, and, in conclusion, refer to the manner in which the method of extraction founded on them might be most advantageously carried out on a large scale.

1. One of the oldest modes of producing copper in the wet way is the precipitating it, by means of metallic iron, from the water of mines, or that resulting from lixiviating old waste-heaps in their neighborhood. These waters contain the copper in the form of sulphates, derived doubtless from the oxidation of sulphuret ores. This process is or was not long ago carried on at Schmöllnitz and Neusohl in Hungary, at Moldava in Croatia, in Anglesea, and at Rammelsberg in the Lower Hartz.

* Geology of Canada, page 736.

2. Closely allied to this process is the one still followed at Faldal in Norway, where an artificial oxidation takes the place of the natural oxidation of similar ores. They are roasted in heaps, and then lixiviated.

3. At Stadtbergen in Westphalia, and at Linz on the Rhine, the vapors evolved in roasting various sulphurets are brought into contact with poor ores containing malachite, and with oxidized ores containing cupric oxide. After these have been acted on for several weeks, they are lixiviated in the usual manner.

4. Dilute muriatic and sulphuric acids, hyposulphite of soda, and even ammonia, have been proposed and occasionally used for dissolving out the copper of oxidized ores.

5. Much resembling the process mentioned under 2, is the method in which the oxidation is performed by calcining in reverberatory furnaces. At various Russian smelting works and in Mansfeldt this process is applied, but in no case does the extraction appear to be at all complete. A large quantity of the copper is removed in the soluble form, but fully as much remains in the residue, which is subject to further metallurgical treatment.

6. The first stage of Bankart's process is the same as the foregoing ones. Rich Cuban sulphurets are first calcined by themselves in reverberatory furnaces, and then lixiviated; the residues are mixed with a fresh portion of raw ore and again calcined. The peroxide of iron contained in the calcined ore causes the conversion into sulphuric acid of a portion of sulphur which would otherwise escape as sulphurous acid. The additional amount of sulphuric acid thus formed contributes of course to rendering the copper soluble. This principle is doubtless correct, but there appear to have been other circumstances which interfered with the practical application of the process.

7. Longmaid calcines pyritous ores with common salt, and then lixiviates. In his process there is doubtless a larger amount of copper rendered soluble than when the sulphurets are calcined alone; but the residues, even when abundance of sulphur is present, are far from being free from copper. The process which I have adopted in the experiments about to be described may be said to be a combination of the two last mentioned methods,—Bankart's and Longmaid's.

8. Henderson's process differs from Longmaid's merely in this particular, that the calcination is performed at such a temperature as to cause the volatilization of the copper in the form of a sub-

chloride. The latter is condensed and treated further. This process labors under the same disadvantage as Longmaid's with regard to copper in the residues.

Among the various processes just enumerated, those which are most advantageous in economical respects, and which are best suited to the local circumstances of Canada, are evidently those in which few or no extraneous substances are required to render the copper soluble, and in which the acid necessary to form the soluble salt of copper is derived from the oxidation of elements present in the ore itself. At first sight the simplest and possibly most efficient means of rendering the copper soluble would appear to be that of merely calcining the sulphuret ores and lixiviating the product. Almost all such ores, whether containing copper glance, purple copper, or copper pyrites, certainly yield by such treatment more or less of their copper in a soluble state; but the amount of the metal so yielded in proportion to the quantity contained in the ore, is invariably very small indeed. Even with ores which contain a very considerable excess of sulphur, the calcination must be very carefully conducted if the extraction is at all to approach completeness. In the first stage of calcination sulphurous acid is given off; in the second sulphate of iron is formed; during the third stage it is necessary to heat the charge rather strongly in order to decompose the sulphate of iron, and transfer its sulphuric acid to the oxide of copper. In so doing there is a danger of too much heat being applied, and even of the sulphate of copper being decomposed. It is therefore extremely difficult to regulate this process, and the disadvantages of its being performed at too low a temperature consist not only in the extraction being imperfect, but also in the deposition of basic salts of iron while the copper is being precipitated. In this way the latter becomes so contaminated that many specimens of copper produced by cementation do not yield by assay over 60 per cent of the pure metal.

These disadvantages are to a very great extent removed by the use of common salt. By its action the sulphate of iron first formed is decomposed at a low temperature, and sulphate of soda and chloride of iron produced. The latter seems to be easily decomposed, and its chlorine transferred, in part at least, to the copper. On treating the calcined product with water, a solution is obtained which is very pure, often containing merely a trace of iron, in which case the deposition of basic iron salts becomes impossible. But although common salt may remedy the defects here indicated,

it cannot make up for a deficiency of sulphur in the original ore; and with or without common salt that ore will be treated with the greatest advantage which contains the largest proportion of sulphur. In proof of this the two following experiments may be cited:

1000 grains of slimes from the Bruce Mines, containing 5.20 per cent. of copper in the state of copper pyrites, but no admixture of iron pyrites, were calcined with 100 grains of common salt. The result yielded to water 13.7 grains of copper. Hence only 37.9 per cent. of the copper was extracted.

500 grains of ore from Escott, containing 10.4 per cent. of copper and an admixture of iron pyrites, were calcined with 100 grains of salt. The product yielded to water 40 grains of copper. Consequently 76.9 per cent. of the metal was removed.

In reflecting on the necessity of a sufficient supply of sulphur, it occurred to me that any means which would facilitate the conversion of the sulphur into sulphuric acid, instead of allowing it to escape as sulphurous acid, would be of advantage if applied in such calcining operations as those here referred to. Having in former experiments* demonstrated that the addition of peroxide of iron increased the amount of sulphuric acid formed in such calcinations, it occurred to me that it might be possible even with an ore containing no more sulphur, in proportion to the copper, than copper pyrites, to convert so much of it into sulphuric acid, as would in the presence of common salt develop sufficient chloride to render the whole of the copper soluble. I accordingly calcined the following materials together:

200 grains copper pyrites.
 400 grains ferric oxide.
 200 grains salt.
 —————
 800 grains in all.

The copper pyrites, which was from Escott, contained 23.5 per cent.; = 47 grains of copper. The residue after calcination weighed 657 grains, and on analysis gave—

Insoluble iron oxide.....	67.9
Insoluble cupric oxide.....	2.2 = 1.8 copper.
Sulphate of soda.....	10.1
Chloride of copper.....	3.4 = 1.6 copper.
Chloride of sodium (by difference)...	16.4
	—————
	100.0

* Canadian Naturalist, vol. vii, p. 196.

From this it appeared that in the residue there were present of copper—

In an insoluble state....	11.82	grs. =	25.15 per cent.
In a soluble state.....	10.51	" =	22.36 "
			<hr style="width: 20%; margin: 0 auto;"/>
			22.33 grs.
Amount of copper lost..	24.67	" =	52.49 "
			<hr style="width: 20%; margin: 0 auto;"/>
			47.00 grs.

The only way in which this extraordinary loss of 52.49 per cent. can be accounted for, is by supposing it to have been volatilized; and other circumstances confirm this view. The calcined substances contained 66.35 grains of sulphate of soda. Consequently 53.11 grains of common salt must have been decomposed, and 32.08 grains of chlorine liberated from it. Of this, 11.82 grains are found in combination with the copper in a soluble state. The remaining 20.26 grains were more than sufficient to form sub-chloride with the 24.67 grains of copper volatilized. The whole of the 32.08 grains of chlorine were not however sufficient to convert the forty-seven grains of copper contained in the ore into soluble protochloride.

From this experiment it became evident, 1st, that even with the use of a large quantity of peroxide of iron, it is difficult to treat copper pyrites so as to produce enough of sulphuric acid to render all the copper soluble; and 2nd, the calcination must be performed at as low a temperature as possible, in order to prevent the volatilization of the copper. The experiment was therefore performed a second time, care being taken to keep the temperature low. The same materials, in the same proportions, were used, and the product this time from the 800 grains weighed 792 grains, and contained—

Iron oxide and other insoluble matter..	66.00
Sulphate of soda.	17.60
Chloride of copper	9.64 = 4.55 copper.
Chloride of sodium (by difference)....	6.76
	<hr style="width: 20%; margin: 0 auto;"/>
	100.00

Thirty-six grains of copper out of the original forty-seven were this time removed in a soluble form; equalling seventy-six per cent, instead of the twenty-two per cent, of the former experiment. Further, it appears that 139 grains of sulphate of soda were formed; and consequently 111 of chloride of sodium decomposed, and sixty-

seven of chlorine liberated. The latter quantity was sufficient to convert fifty-nine grains of copper into proto-chloride. It becomes therefore difficult to say why the whole copper contents, 47 grains, were not extracted. Since the temperature was kept very moderate, the only other cause which may possibly have affected the result unfavorably, was the continuing of the calcination beyond the proper point, and the consequent decomposition of proto-chloride into insoluble sub-chloride of copper.

In order to ascertain whether the copper unaccounted for in the last experiment remained in the residue or was volatilized, the following experiment was made.

200 grains copper pyrites.
 500 grains iron oxide.
 200 grains salt.
 —————
 900 grains were mixed together.

The pyrites contained 23.6 per cent, equal to 47.2 grains of copper. The mixture was calcined at a low temperature until the evolution of sulphurous acid and then of chlorine ceased. The result weighed 911 grains, and contained—

Iron oxide and other insoluble matter....	67.33	
Cupric oxide.....	1.87	= 1.5 copper.
Sulphate of soda.....	12.6	
Chloride of copper.....	8.14	= 3.8 copper.
Chloride of sodium (by difference)	10.06	
	—————	
	100 00	

It is evident from this that seventy-three per cent of the copper contained in the original ore was rendered soluble, and that twenty-seven per cent was left in the residue insoluble, but whether in the state of sub-chloride or oxide I did not ascertain. If we calculate from the amount of sulphate of soda formed in this experiment, it would appear that but a very little more chlorine was developed than was necessary to take up the whole of the copper as proto-chloride, so that it is most reasonable to suppose that the copper which remained insoluble was in the state of oxide, and had never had an opportunity of uniting with chlorine. The result of the experiment as to the volatilization of the copper was decisive, inasmuch as the whole of the copper was found in the product; therefore none could have been sublimed. The experiment also indicated that in order to a perfect extraction, an excess of chlorine must be presented to the copper.

It will be recollected that the experiments just described were made with an ore poor in sulphur; containing no more of that element in proportion to the copper than is contained in copper pyrites. The results not proving satisfactory, I proceeded to experiment upon ores containing more sulphur, taking care always to keep the temperature very low, and to interrupt the calcination so soon as the development of sulphurous acid had ceased, and while that of chloriue and other gases was going on. The following are some of these experiments, with their results:

500 grains ore from Escott, containing 10·4 per cent copper (and both iron pyrites and copper pyrites), were calcined with 500 grains of iron oxide and 200 grains of salt. The product weighed 1184 grains, and gave with water a solution from which iron precipitated 49·6 grains of copper. Since fifty-two grains were present in the ore operated on, it is evident that 94·2 per cent of the copper was removed in a soluble form.

500 grains ore from Escott, containing 4·5 per cent of copper, and a considerable amount of iron pyrites, were calcined with 100 grains of iron oxide and 100 grains of salt. The result weighed 618 grains, and when heated with water yielded a solution containing 22·2 grains copper. 22·5 grains were present in the original ore; hence 97·7 per cent of the copper was dissolved.

300 grains of the same Escott ore, with 4·5 per cent of copper, 300 grains of ore from Bruce Mines containing 8·7 per cent of copper (and no iron pyrites), 300 grains of iron oxide, and 300 grains of salt, were calcined until chlorine was strongly developed. The result treated with water gave a green solution containing thirty-six grains of copper. Since the ore used in this experiment contained 39·6 grains copper, 90·9 per cent of the metal was removed in a soluble state.

300 grains of Bruce Mine ore of 8·7 per cent, 200 grains of iron pyrites from Brockville, 300 grains of iron oxide, and 200 grains of salt were calcined in the manner above mentioned. The product gave with water a solution containing 27·1 grains copper. The ore contained only 26·1 grains, and the excess may have been derived from the iron pyrites. In this case, therefore, the whole of the copper of the ore was dissolved.

The same mixture as the preceding, calcined for a longer time, yielded only 14·5 grains of copper in a soluble state.

400 grains of Bruce Mine slimes of 5·1 per cent, 400 grains of iron oxide, 100 grains of pyrites from Brockville, and 100 grains

of salt yielded, on calcination, a product from which water dissolved 18.6 grains of copper. The ore contained 20.4 grains; hence 91.1 per cent of the copper were dissolved.

200 grains of Escott copper pyrites of 23.6 per cent, 100 grains of iron pyrites, 800 grains of iron oxide, and 200 grains of salt were calcined together. The product weighed 1349 grains, from which water dissolved 46.6 grains of copper. Consequently ninety-eight per cent of the copper contents of the ore were rendered soluble.

In order to prove that the iron oxide is essential to producing this favorable result, the last experiment was repeated, the iron oxide being excluded from the mixture. On calcining and lixiviating, only 33.4 grains of copper were dissolved; that is, seventy per cent only instead of ninety-eight per cent.

The foregoing experiments were performed on plates of fire-clay in the muffle of a cupelling furnace. The iron oxide used was prepared by calcining iron pyrites with salt, and then lixiviating and drying. The following trials were made in a manner approximating more to the method that would necessarily be adopted in carrying out the process on a large scale. The mixtures were merely stirred on an iron plate lying upon two ignited billets of wood in a common stove. And further it will be seen that the oxide of iron necessary in the process was obtained from the ore experimented on. This ore was from the Capel Mine near Lennoxville, and had the following chemical composition:

Copper	8.60
Iron	30.31
Sulphur (by difference).....	34.34
Silica and argillaceous matter.....	26.75
	<hr/>
	100.00

These figures correspond to the following mineralogical composition:

Copper pyrites	24.72
Iron pyrites.....	49.79
Quartz, &c.....	26.75
	<hr/>
	101.26

It may be said that in round numbers this ore consisted of one half iron pyrites, one fourth copper pyrites, and one fourth rock. The first calcinations made with it were principally for the purpose of obtaining the necessary iron oxide. Nevertheless, the quantity of copper extracted was at the same time determined.

10,000 grains of the ore were first calcined with 2,000 grains of salt, and without oxide of iron. The result weighed 10,860 grains. Water, extracted from it 0·8 per cent of copper, and diluted sulphuric acid dissolved further a quantity of flocculent matter containing 1·8 per cent. Of the 860 grains copper contained in the original ore there were therefore,

Dissolved by water.....	86·88 grains = 10 per cent.
Dissolved by dilute acid.....	195·48 " " 22 "
Left in the residue.....	577·64 " " 68 "
	—————
	860·00

The product of the foregoing experiment after lixiviation and drying assayed 6·4 per cent. copper. A second calcination was performed with it and other substances having copper contents, as follows :

400 grains lixiviated product of above experi-	
ment containing 6·4 per cent.....	= 256 grains copper.
2000 grains fresh ore of 8·6 per cent.....	= 172 "
1200 grains salt.....	
	—————
7200 grains mixture with.....	428 grains copper.

After being calcined in the usual manner the whole weighed 7850 grains, and contained four per cent of copper soluble in water slightly acidulated with sulphuric acid, and 1·11 per cent of copper insoluble therein. Of the 428 grains there were therefore,

Dissolved.....	314 grains.
Left insoluble.....	87 "
Unaccounted for.....	27 "
	—————
	428 grains.

Thus 73·3 per cent of the original copper contents were obtained in a soluble form.

The product of the foregoing experiment was, as in the first case, lixiviated and dried. It then contained $1\frac{1}{3}$ per cent of copper, and was calcined a third time, with fresh ore and salt in the following proportions :

4800 grains residue with $1\frac{1}{3}$ per cent....	= 64·0 grains copper.
2400 grains fresh ore of 8·6 per cent.....	= 204·5 "
1440 grains common salt.....	
	—————
8640 grains, containing.....	270·4 grains copper.

This mixture was treated in the usual manner. The product weighed 8900 grains, and contained

Soluble.....	2.77 per cent.	= 246 grains copper.		
Insoluble.....	.25 "	22.2 "	"	"
Unaccounted for.....	1.3 "	"	"	"
		<hr/>	270.4	" "

Thus 91.4 per cent of the copper contained in the ore originally used was recovered in a soluble form.

The residue from the experiment last described, after thorough lixiviation and drying, contained 0.44 per cent copper. Now very few of the slags from copper furnaces contain less than this per centage, and the refuse products of ordinary ore in dressing-operations seldom assay less than 1.5 per cent. In having produced therefore a residue containing as low a percentage as the above, it may be assumed that a point was raised where its copper contents might be disregarded. This residue consists, however, almost exclusively of iron oxide and the earthy matrix of the ore, and by virtue of the former is of value for mixing with fresh ore to produce the oxidation of the sulphur, and the consequent extraction of the copper contained therein. In order to test its usefulness in this respect a fourth calcination was made, with the following mixture:

2000 grains residue of 0.44 per cent	= 8.8 grains copper.
1000 " fresh ore of 8.6 "	= 86 "
600 " salt.....	
<hr/>	<hr/>
3600	94.8 grains copper.

The product weighed 3710 grains, and contained as follows:

Iron oxide and insoluble matter.....	72.13	
Cupric oxide insoluble in water and dilute sulphuric acid.....	.27	= 0.22 copper.
Cupric oxide soluble in dilute sulphuric acid.....	.13	= 0.11 "
Sulphate of soda.....	19.22	= 4.33 sulphur.
Chloride of copper.....	4.7	= 2.22 copper.
Perchloride of iron.....	1.42	
Chloride of sodium, by difference.....	2.13	
	<hr/>	100.00

Of the 94.8 grains copper contained in the original ore, there were consequently

Dissolved by water.....	82.36 grains	= 86.88 per cent.
Dissolved by dilute acid..	4.08 "	= 4.3 "
Left in residue.....	8.16 "	= 8.6 "
Unaccounted for.....	.20 "	= .22 "
	<hr/>	94.80

If however we neglect the 8·8 grains copper contained in the residue used, which it is perfectly reasonable to do, then 95·7 per cent. of the copper in the ore is dissolved in water alone, and the whole of it on the additional use of a slight quantity of dilute sulphuric acid. One of the most striking facts deducible from the results of this experiment is that 46·64 per cent of the sulphur contained in the original ore was converted into sulphuric acid, and then into sulphate of soda. The amount of chlorine liberated by the formation of such a large quantity of this salt, must have been greatly in excess of what was necessary to render the copper soluble.

On account of this latter circumstance I attempted to reduce the quantity of salt used, and made four calcinations in the proportions of two parts of residue, one part of fresh ore, and one fourth of a part of salt. The ingredients, used with their copper contents, were as follows.

	1.	2.	3 & 4.
Residue.....	GRS. 2000 with 8·8 Cu	GRS. 1500 with 6·6 Cu	GRS. 2000 with 20 Cu
Fresh ore.....	1000 " 86·0 "	750 " 64·5 "	1000 " 86 "
Salt.....	250 "	175 "	250 "
	-----	-----	-----
	3250 with 94·8 Cu	2425 with 71·1 Cu	3250 with 106 Cu

The products of these four experiments contained of copper respectively:

	1.	2.	3.	4.
	GRS.	GRS.	GRS.	GRS.
Soluble in water.....	59·11	40·5	62·22	66·00
Soluble in dilute SO ₃	14·69	7·3	3·60	10·00
Insoluble.....	} 21·00 {	7·3	18·18	17·21
Unaccounted for.....		16·0	22·00	12·79
	-----	-----	-----	-----
	94·8	71·1	106·00	106·00

These results were by no means encouraging, yet the quantity of salt was quite sufficient for chloridizing the copper. One fact must however be mentioned with regard to these trials; they were very diligently stirred during the calcination.

No other resource was left but to return to experimenting with a larger quantity of salt. Accordingly the following ingredients were mixed and calcined :

2950 grains residue of 1·0 per cent. =	29·5 grains copper.
1500 " fresh ore of 8·6 " =	129·0 " "
750 " salt.....	
-----	-----
5200 grains containing.....	158·5 grains copper.

They gave a product weighing 5270 grains, and containing

2.33 per cent Cu soluble in water	=	122.79
0.22 " " in dilute acid	=	11.59
0.33 " insoluble	=	17.16
Unaccounted for	=	6.96
		<hr/>
		158.50

Neither was this result extremely satisfactory. This mixture also was stirred diligently during the operation.

In order to ascertain whether the stirring exercised any injurious effect upon the completeness of the extraction, the following mixture was calcined:

2000 grains residue of 1.1 per cent	=	22 grains copper.
1000 " fresh ore of 8.6 "	=	86 "
500 " salt.....		
		<hr/>
3500 grains containing.....		108 grains copper.

The operation was performed with as little stirring as possible, and the result weighed 3800 grains, containing

2.55 per cent soluble in water	=	96.90 grains copper.
.22 " " in dilute acid	=	8.36 "
.22 " left insoluble	=	4.18 "
		<hr/>
		109.44

It will be seen that this calcination was eminently successful, and that all the copper contained in the fresh ore was extracted. It was therefore very evident that diligent stirring was injurious.

Encouraged by this result I repeated the calcination with the smaller quantity of salt which I had previously used; the mixture being left almost wholly undisturbed during the operation. The ingredients were

2000 grains residue of 1.1 per cent	=	22
1000 " fresh ore of 8.6 "	=	86
250 " salt.....		
		<hr/>
3250 grains with.....		108 grains copper.

They gave on calcination a product of 3405 grains, containing 2.77 per cent, equal to 94.31 grains copper soluble in water; a result conclusively establishing that the more undisturbed the materials are during calcination, the more complete is the extraction.

The foregoing experiment was performed with one fourth part of salt to one of fresh ore. The result having been satisfactory,

the following mixture containing only one fifth part of salt was calcined :

2000 grains residue of 1·1 per cent	= 22 grains copper.
1000 " fresh ore of 8·6 " "	= 86 " "
200 " salt.....	
3200 grains containing.....	108 grains copper.

This experiment was made with the same care as the others, and with as little stirring as possible. The result weighed 3250 grains, and contained

2·33 per cent. soluble in water	= 76·7 grains copper.
·44 " " in dilute acid	= 14·3 " "
Unaccounted for	= 17·0 " "
	108·0

Since therefore only 71 per cent of the copper was extracted, it follows that one fourth of salt is the minimum quantity which can be used, and at the same time a complete extraction accomplished.

I here closed this series of experiments, having obtained all the definite results sought for. It appears certain that 95 per cent of the copper contained in an ore such as that produced by the Capel mine can be extracted in the humid way by calcining it with twice its weight of impure iron oxide (perhaps less would be sufficient), and one fourth of its weight of salt; provided always that the operation is performed at a very low temperature, that it is not continued beyond a certain point, and that while it is going on the materials are stirred as little as possible. Whether equally good results can be obtained in practically applying this process, is a matter which can only be decided by experience; but there appears to be no reason for doubting that it would be completely successful on the large scale.

REVIEW.

GEOLOGY OF NEW BRUNSWICK.*

It would appear from these reports that two surveys of the Province of New Brunswick proceeded simultaneously, in the summer of 1864; the one under Prof. Bailey being limited to Southern New Brunswick, the other, under Prof. Hind, embracing a general reconnoissance of the whole Province. It results from this that some of the same subjects are discussed in both reports, which must have occasioned some loss of time to the observer, as it does to the reader. On the other hand the people of New Brunswick have an opportunity of comparing the work of their own geologists, Bailey, Matthew, and Hartt, with that of a naturalist of some experience and of large and varied information.

Without any invidious comparison, we may say that Prof. Bailey's Report is distinguished for clearness, systematic arrangement, and careful attention to details; and that its execution must have involved a large amount of laborious field-work. Prof. Hind's is more discursive and popular in style, and in a less amount of local facts brings to bear a great mass of varied information derived from many sources.

Passing by facts relating to economic geology, of which many of great importance to New Brunswick are contained in these reports, we may notice some points of interest in scientific Geology.

Prof. Hind thus describes the occurrence of the "Quebec Group" of rocks in New Brunswick:—

"The supposed northern boundary of this formation within the limits of the Province, commences near the Medisco River on the Bay de Chaleur. The strike of the rocks would carry them to Ramsay's Brook on the Upsalquitch, and thence towards the headwaters of the Tobique to the north of Nictau Lake.

"A few miles from the mouth of the Tobique there are a series

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- * 1. Observations on the Geology of Southern New Brunswick, made principally by Professor D. W. Bailey, Messrs. George F. Matthew, and C. F. Hartt; prepared and arranged, with a Geological map, by L. W. Bailey, A.M., &c., &c. Pp. 158.
 - 2. A Preliminary Report on the Geology of New Brunswick, together with a special Report on the Distribution of the Quebec Group in the Province; by Henry Youle Hind, M.A., F.R.G.S., &c. Pp. 293.

of silicious slates which appear to underlie unconformably a series of Upper Silurian argillites, green, red, and blue-black, and holding *Fuvsites Gothlandica*. The strike of these silicious slates would carry them to the north of Nictau Lake, and this line prolonged in a southwesterly direction is supposed to form a rude but continuous curve, which may provisionally represent the northern boundary of the Quebec Group, which has been brought to the surface simultaneously with the granite axis of Devonian age described in Chapter II.

“The continuation of this boundary takes a southerly course and is supposed to cross the Shiktechawk about $3\frac{1}{2}$ miles from its mouth, where a conglomerate occurs, described in Chapter VI. It crosses the Saint John below Presquile, and taking a southwesterly course it enters the State of Maine near the forks of the Meduxnekeag, pursuing its course towards the Atlantic Ocean on the north flank of the granitic axis, where it is represented on Mr. C. H. Hitchcock's Map of Maine as a belt of mica schist. On the south-east side of this axis the Quebec Group is again brought to the surface, its eastern boundary being in great measure covered up by the Bonaventure formation or base of the carboniferous series, which in many places reposes upon it horizontally or nearly so. Until further investigations establish the contrary, all the sedimentary rocks, with the exception of the carboniferous, north of the granitic axis, which comes in from the State of Maine at Saint Stephens, and proceeds in an easterly direction through Queen's County to and beyond the Saint John, may be considered as belonging to this group, although it is not improbable that there is a narrow belt of middle silurian rocks, on the north-east flank of the carboniferous series a few miles due west of Fredericton. The rocks on the north side of this last-named axis, described by Hitchcock as mica schist, in its prolongation through Maine to the Atlantic Ocean, most probably belong to the Quebec Group.

“The breadth of this group of rocks measured at right angles to the strike within the limits of the boundaries just described, will be approximately as follows, after deducting the granite axis :

1. Five miles from Bathurst,	....	....	....	20 miles.
2. From Ramsay's Brook, southeasterly,	....	....	....	36 “
3. From near the Nictau	“	....	....	44 “
4. From the Tobique,	“	....	....	43 “
5. From the Maduxnekeag,	“	....	....	38 “
6. On the New Brunswick and Canada R. R.,	....	....	....	25 “

“It has been already stated that this granite axis (Chap. II) is really composed of numerous narrow belts, which come up between the schists of the Québec Group, also that it has a much more northerly extension than represented by Dr. Gesner. On the South-west Miramichi, there are no less than ten distinctly parallel granite belts, with belts of slate and schist between them. It is clear that this arrangement of the granite and slates may exercise a very important influence upon the rocks now under review, as it not only extends the area over which they may be found, but the metamorphic action exhibited by the granite may have effected a material change in the composition and crystalline arrangement of some of the strata.”

DEVONIAN INSECTS.

A very striking new fact in Prof. Bailey's Report is the discovery of insects in the Devonian of St. Johns by Mr. Hartt,—the first instance on record of insects so old. These remains are thus described by Mr. Seudder in a letter to Mr. Hartt:—

Boston Society of Natural History,

January 11, 1865.

“MY DEAR MR. HARTT,—I have made as careful an examination as my present circumstances will permit, of your most interesting collection of the fossil remain of insect-wings from Lancaster. There are ten specimens in all, eight of which are reverses of one another, thus reducing the number to six individuals; of these, one, a mere fragment, belongs, I think, to the same species as another, of which the most important parts of the wing are preserved, so that we have five species represented among these Devonian Insects, and these remains are all, I suspect, composed of portions of the anterior wing alone. The data being thus fragmentary, the conclusions cannot be quite so satisfactorily determined as we could wish, but we can still discover enough to prove that they are of unwonted interest. Besides the peculiar interest which attaches to them as the *earliest known traces of insect life on the globe*, there is very much in themselves to attract and merit our closest attention.

“One of them is a gigantic representative of the family of *Ephemera* among Neuroptera, some three or four times the size of the largest species now living, with which I am acquainted.

“Another borrows some striking points of the peculiar wing-struct-

ture of the Neuropterous family *Odonata*, and combine with them those of families remote from that, and even belonging to a distinct section of the Neuroptera, exhibiting to our view a synthetic type which combines in one the Pseudoneuroptera and the Neuroptera, and represents a family distinct from any hitherto known.

“Other fossil insects, found in carboniferous concretions in Illinois and described in Silliman’s Journal (N. S. xxxvii, 34), which Professor Dana has kindly allowed me to examine,* also belong to hitherto unrecognized families, exhibiting similar relations to these in-our-day-disconnected Sections of Neuropterous insects; and your third species is a member of still another family of Neuroptera, which finds its natural relations between the two described by Professor Dana.

“A fourth, of which only an important fragment was found, would seem to belong to the Neuroptera, but by some peculiarities of the minuter cross-veins, thrown off in the middle of the outer edge of the wing, in a most irregular and unusual manner, suggests no intimate relations with any known family, but must have belonged to a group of large and weak-winged insects.

“The fifth and last to be mentioned is of very striking interest, because, while it exhibits the peculiar venation which forms the well-known tympanum or stridulating apparatus of the male, in the Orthopterous *Locustariæ* (though differing somewhat from that), it also most resembles the Neuroptera in all or nearly all the other peculiarities of its structure, and suggests the presence in the insect-faunæ of those ancient times of a synthetic type, which united the characteristics of the Orthoptera and Neuroptera, in themselves closely allied; this point, however, requires patient and severe investigation, and only my earliest impressions are here recorded, made, however, immediately after a close examination into the relations of other fossil insects.

“I earnestly hope that this locality, from which these remains were disinterred, may receive a most careful and thorough examination by yourself, who have already shown so much diligence and careful scrutiny in the discovery of such important and easily overlooked remains. Hitherto, the study of fossil insects has been mainly confined to those of much more recent date, and has resulted in shedding comparatively little light upon geological and palæontological questions; but these few remains, coupled with the pair of insects found in Illinois, induce us ardently to anticipate that the future study of fossil insects, drawn from such ancient

strata as these, may lead to as brilliant and important results, in the elucidation of geological problems still open, in widening the range of our palæontological horizon, and in our general knowledge of the history of Life on our globe in all its bearings, as have been reached by the study of the remains of animals of a more substantial structure, but which have hitherto been denied to the student of fossil Entomology."

The following, from Prof. Hind's Report, on glacial striation in New Brunswick, is also of interest, even to those who prefer icebergs to glaciers as a means of effecting such striation.

ACTION OF GLACIAL ICE.

"Whenever the loose covering of clay and sand is swept off the solid rock throughout the whole extent of this Province, glacial striæ are visible; in other words, the rocks are seen to be polished, striated and sometimes deeply grooved. These striations are observed at all altitudes, but they have been obliterated over wide areas by atmospheric influences. During the past summer I saw them on the summit of Blue Mountain, 1650 feet above the sea. There small surfaces of a very hard metamorphised conglomerate are beautifully polished and striated. They abound throughout the slate region of the Province, the slate receiving with ease and retaining with much persistency the markings produced by the slowly moving glacial mass.

"The general direction of these striæ is N. 10° W.; but there are often two sets to be seen, differing in direction by two or three degrees. The best place within a few miles of Fredericton for examining these striæ under very singular circumstances, is in Prince William Parish, at and near the antimony mines. On the road to the mines leading from the main post road the striæ are beautifully retained on the polished surface of a hard silicious slate. The country in that vicinity has been ground away and removed by ice to a vertical depth of some hundred feet, as has, indeed, a considerable portion of, if not the whole, of the Province.

"In Prince William, however, an observer can not only see the 'tracks' of the glacial mass graven on the rocks, but he can also see the work it has accomplished in excavating Lake George. He can trace the course of the glaciers far beyond Lake George (442 feet above tide) and Bear Lake; see it in imagination sweeping past the edge of the Plateau of the Carboniferous series, which t

has worn away to an escarpment west of Oromocto Lake, and as a glacial stream passing down the valley of the Magaguadavic to the sea.

“ The western extremity of the Coal Measures holds up Lake Oromocto. It has been denuded away by lateral glacial action towards the west, until we have the remarkable spectacle presented of a bold escarpment facing the west, holding up a Lake containing 10,000 acres, and 115 feet above the valley it overlooks. Lake Oromocto is 370 feet above the sea, the scarpment which overlooks the Magaguadavic is 394 feet, and the river itself flowing at the base of the escarpment is 256 feet above the same level.”

GENERAL DIRECTION OF THE ICE-FLOW IN NEW BRUNSWICK.

The polishing of some of the harder rocks is extremely beautiful, and shows that the action of the ice slowly moving over it must have continued for an exceedingly long period of time. It is not to be supposed that the ice had uniformly one direction: on the contrary, its direction may have varied through an entire quadrant under different conditions. When we look at glacial striae we see only the last record of the moving mass, the last impression of its presence; but in what direction it moved, or with what effect at any period before the graving of its last striations, we can only conjecture.

An inspection of the preceding table, although it is very imperfect, will show that the direction of the moving mass of ice was generally nearly due north and south. As the glaciers approached the sea they accommodated themselves to the sinuosities of the valleys through which they made their escape, and produced striations in different directions. At a greater elevation and more inland, what were on the sea-shore mere ice-streams, would be in the interior a uniform or broad glacial mass. Suppose for instance that a mass of ice several hundred feet thick, like that which now covers in part the surface of Greenland,* once extended over the

* “ To have a correct idea of the glacier accumulation in Greenland, we must imagine a narrow continent of ice flanked on its seaward sides by a number of Islands, and in every other direction lost to vision in one continuous and boundless plain. Through the spaces between these apparent Islands, the enormous glacial accumulations lowly seek their passage to the sea, and send off an annual tribute to encumber, to cool, and to dilute the waters of the adjoining ocean. The average height or depth of the ice at its free edge in these intervals or valleys between the

entire surface and flanks of the granitic highland range to the north and northeast of the Saint John. During its slow movement tow-

IN THE FOLLOWING TABLE ARE GIVEN THE DIRECTION AND LOCALITY OF SOME OF THESE GLACIAL STRIÆ.

*Table showing the Direction of Glacial Striæ in New Brunswick.**

No.	Kind of Rock.	Locality.	Height above the Sea.	Direction.
1	Grey Grits,	Fredericton,	About 350 feet,	N. 10° W.
2	Silicious Slate,	Prince William,	" 400 "	N. and S.
3	Grey Grits,	Four miles on Mira- michi Road,		N. 10° W.
4	" "	Hanwell Road, †	" 400 "	N. 10° W.
5	" "	Maryland Road,	" 400 "	N. 10° W.
6	" "	" "	" 400 "	N. 10° W.
7	Red Sandstone,	" "	" 400 "	N. 10° W.
8	Greenstone,	Gagetown Road,		N. and S.
9	Conglomerate,	Near mouth of Kes- wick,		N. N. W.
10	Reddish Conglo- merate,	Near Gagetown,		N. 22° W.
11	Conglomerate,	Oromocto Lake	" 370 "	N. N. W.
12	"	Harvey Settlement,		N. and S.
13	Red Sandstone,	9 miles south of Saint Andrews,	" 60 "	W. by W.
14		Chamcook Lake Shore,		N. N. W.
15		On high land near St. Andrews.		N. by W.
16	Trap,	L'Etang,	" 100 "	N. 45° W.
17	"	Magaguadavic Falls		N. W.
18	Granite,	East of Musquash Valley,		N. 20° E.
19	Slates,	Near Penitentiary, Saint John,		N. 30° E.
20	Syenite,	South Bay,		N. 25° E.
21	"	Mouth of Nerepis,		N. W.
22	"	Oxbow of "		N. N. W.
23	Grey Grits,	Old Woodstock Road,		N. 10° W.
24	Slates,	Spring Hill,		N. 10° W.
25	Purple Sand- stones,	Gonish Road,		N. 10° W.
26	Metamorphosed Conglomerate,	Blue Mountain,	" 1650 "	N. and S.
27	Grits,	Opposite Frederic- ton,	" 350 "	N. 10° W.

projecting points of coast is 1200 or 1500 feet, of which about one eighth or 150 feet will be above the water. In some of the valleys, however, the depth is upwards of 2400 feet. These phenomena can be seen at the

* Some of these observations were recorded by the late Dr. Robb.

† Between Fredericton and Hanwell, very numerous and uniformly. N. 10° W.

ards the sea it would not only bring with it the materials it tore off the rocks over which it was passing, but it would also score and polish the rocks themselves. At that period the valley of the Saint John was probably, but not necessarily, filled with drift. The glacial mass passed over it towards the sea, scratching and polishing the rocks during its slow but irresistible journey. Approaching the sea it would probably split into tongues, chiefly on account of its moving eccentrically, and thus covering a larger area owing to the figure of the earth; and by reason of climate these tongues would reach the sea as ice rivers, in process of time excavating for themselves deeper channels, which ultimately became 'Fiords' or deep bays where the glaciers 'calved,' to use the term commonly employed in Greenland, and gave off their icebergs. An inland glacier having, as it were, once established itself in any determinate geographical position, would, in process of time, assisted by its own glacial river, wear out a lake-basin.*

Prof. Bailey and Mr. Matthew have worked out with much labor and success the complicated geology of the rocks in the vicinity of St. John, and have ascertained the fact that these include representatives of the Lowest Silurian beds, and probably of the Laurentian and Huronian. We shall give in our next number their account of the oldest fauna found in that neighborhood.

MISCELLANEOUS.

A NEW AMERICAN SILKWORM.—After numerous experiments, Mr. L. Trouvelot, of Medford, Mass., U.S., has succeeded in rearing successfully, and in great numbers, *Attacus Polyphemus*, Linn., and in preparing from its cocoon an excellent quality of silk, possessing

present day in Baffin's Bay and Davis' Straits." "As we advance northwards along the coast of west Greenland, and thus diminish the annual mean temperature both of the sea and of the atmosphere, we find the glacier approaches nearer and nearer the coast line, until in Melville Bay, latitude 75°, it presents to the sea one continuous wall of ice, unbroken by land, for a space of probably seventy or eighty miles.—Dr. Sutherland, on the *Geological and Glacial Phenomena of the Coasts of Davis' Straits and Baffin's Bay*.—Proceedings of the Geological Society, 1853.

* See Professor Ramsay's paper "On the Glacial Origin of Lakes".—Journal of the Geological Society, August, 1862.

great lustre and strength, and pronounced superior to Japanese and all other silks, except the best Chinese, by competent judges.

The silk is unwound by a simple process perfected by Mr. Trouvelot, each cocoon yielding about 1500 yards. This insect is very hardy, being found throughout the Northern States and Canada; and, as it feeds upon the leaves of oak, maple, willow, and other common forest trees, may be reared easily in any part of the country.

Mr. Trouvelot has gradually increased his stock from year to year, by raising young from the eggs of the few individuals first captured, until he has at present seven waggon-loads of cocoons, the entire progeny of which he proposes to raise during the coming season.

The thanks of the country are due to the ingenious and persevering author of this successful attempt to introduce a new and interesting field for industry and enterprise, which cannot fail to be a source of profit to those who intelligently engage in it, and of increased wealth and prosperity to the people, should it be developed to the extent that now seems possible.

The first public notice of his experiments with this insect was given by Mr. Trouvelot at a meeting of the Institute of Technology, at Boston, about a year ago, when he exhibited specimens of silk manufactured from it, both natural-colored and dyed.—*A. E. V. in Silliman's Journal.*

BOTANICAL NOTES.—*Aspidium fragrans* Swartz. Our correspondent, Dr. Thomas, has had the good fortune to find this rare fern at Rivière-du-Loup (en bas); its only other Canadian locality certainly known to me is "East shore of Lake Superior in rocky open woods," where it was found by Mr. Barnston in 1859. *Asplenium viride* Hudson, has also been found by Dr. Thomas at the same place; the provincial range of this fern would thus appear to be from Canada East and New Brunswick (Mr. Matthew) to Newfoundland,

Our correspondent, Mr. Macoun, has found *Myosurus minimus* Linn., near Belleville—a very interesting discovery: he also announces *Potamogeton abruptus* Wood, and *Cardamine hirsuta* var. *Virginica* as natives of that neighborhood. W.