GEOLOGICAL SURVEY OF CANADA
A. P. LOW, DIRECTOR.

REPORT

ON THE

COPPER DEPOSITS

OF THE

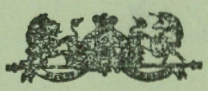
EASTERN TOWNSHIPS OF QUEBEC

WITH A

REVIEW OF THE IGNEOUS ROCKS OF THE DISTRICT

BY

JOHN A. DRESSER, M.A., F.G.S.A.



OTTAWA
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A. P. Low, Esq., B. Sc., F.R.G.S.,

Director of the Geological Survey Department,
Ottawa, Canada.

SIR,—I beg to submit herewith a report on the copper-bearing rocks of southeastern Quebec, with a petrographic review of the district. The field work has been done at intervals during the seasons of 1902-3-4-5. The map illustrating this report is based on the survey of the areal geology of the district by Dr. R. W. Ells (Annual Reports of the Geological Survey, 1886, 1887 and 1904).

I have the honour to be, sir,
Your obedient servant,

JOHN A. DRESSER.

Montreal. April 7th, 1906.

CONTENTS.

THE DISTRICT:

The district discussed in this report lies in that part of the province of Quebec which is southeast of the St. Lawrence river and south of the city of Quebec. It comprises the counties of Stanstead, Sherbrooke, Compton, Beauce, Sutton, Brome, Shefford, Richmond, Wolfe, Arthabaska, Megantic, Lotbinière, Bagot and Drummond. Being the first part of southeastern Quebec to be surveyed into townships after the English manner of survey, instead of division into parishes according to the custom that prevailed during the period of French rule in Canada, the district is commonly known as the "Eastern townships." As will be shown on a later page, this district is distinguished from the rest of the province by a difference of physical features, as well as by the accident of the mode of survey, and so is a natural division of the country.

The settlement of the Eastern townships began about the beginning of the last century, but it was some fifty years later that the hilly portions became sufficiently opened up by settlement for their mineral resources to be made known. By that time a single line of railway, the Grand Trunk, had crossed the district with a line leading from Montreal on the St. Lawrence to Portland on the Atlantic, and a branch line from Richmond, about the central point of the Eastern townships, had also been extended to Quebec.

I.

COPPER MINING IN THE EASTERN TOWNSHIPS.

The occurrence of copper in the Eastern townships was known as early as 1841. In that year Sir William Logan examined a copper bearing property at Carbuncle mountain, Brompton lake. This was one year prior to the organization of the Geological Survey, of which Logan was the first Director.

In 1847 the Geological Survey report called attention to the deposits at Upton, and the reports of succeeding years mentioned or described other localities, until a compilation of these in 1866 gives a list of about five hundred localities in which copper was known to occur in the district. This mineral was vigorously sought for, and extensively mined between the years 1859 and 1866. With the de-

cline in the price of copper which followed this time, from about thirty-five to nine cents per pound, the mining operations received a very severe check, and work for a time almost completely ceased.

In this earlier work copper was the only product of the ore that was then of any considerable value, and the richest sulphur ores were discarded when the percentage of copper was low. But after the intense speculative wave had passed, notwithstanding the low price of copper, between 1875 and 1885 several properties were reopened, or changed management, and were worked on a better economic basis. Not only were the metallic contents of the ores, except the iron, utilized, but the sulphur was also saved, for the manufacture of sulphuric acid and allied products. Thus the mines at Capelton and Eustis have been worked continuously for about thirty years, i.e. ever since their operations have extended to the utilization of the sulphur. A depth of three thousand feet, or thereabouts, has been reached, and although detailed reports are not available the extension of the plants, and other features observable, indicate no diminishing of the works at those well managed and successful mines.

After remaining unworked for a long interval the property known as the Cillis mine, on lot 4, range XI, of Ascot, was reopened, and operated in the same manner by an American company, and a large amount of valuable ore was produced. This mine, known under the new management as the "Howard," only ceased to be worked after the ore body had been followed across the line into the adjoining property, called the King mine. In the King and Suffield mines the development work carried on by the present proprietor, Mr. A. O. Norton, Boston, Mass., has been very successful A large amount of ore has been exposed and important extensions of the work are being projected.

The Moulton Hill mine, a few miles east of Sherbrooke, was worked at the same time as the Howard and under the same management. It seems to have produced about a thousand tons of ore per month during the last year it was in operation. The Ascot mine, in lot 8, range VIII of the township of Ascot, is another of the reopened properties. Under the direction of Mr. John McCaw, one of its owners, this mine is at present producing an excellent quality of ore.

In short, wherever the mining has been carried on with consistent economy; the characters of the ore bodies properly observed in following the ore; the product of the mines utilized to their full value,

and transportation facilities were at least normally favourable, success seems to have followed.

Since the district was first opened the conditions of mining in it have greatly changed. At that time only the Grand Trunk railway crossed the copper-bearing district, and it was from ten to thirty miles distant from the majority of the mines. There have since been added the Canadian Pacific, the Boston and Maine, the Quebec Central, as well as the Orford Mountain, and the Lotbinière and Megantic, two local railways, all of which greatly facilitate transportation for mining purposes. For instance, the mines at Eustis and Capelton, which when opened were seven miles from a railway, are now served by the Boston and Maine railway, which crosses the properties and gives a direct line to Boston and other Atlantic ports. The Suffield, King, Ascot, and several other properties in the southern part of the township of Ascot, which were eight or ten miles from a railway when opened, are at present about equidistant, two miles, from the Boston and Maine on the south and the Canadian Pacific railway on the north. This central locality is one hundred miles from Montreal, three hundred from Boston, and four hundred from New York, with direct lines of railway to each.

The Quebec Central railway reduces the distance of the Harvey Hill mine from a railway, from fifteen miles to seven, and affects most of the other deposits northeast of the St. Francis river in an equally favourable manner. The Canadian Pacific gives access to Roxton and vicinity, and brings the Sweet mine and other deposits of Sutton within one mile of a railway, instead of thirty, as was the case when these were formerly worked. Similarly the Orford Mountain railway has improved the means of access to the copper deposits of Shefford, Ely, and Melbourne.

This opening of the country has not yet proceeded so far as to exhaust the supply of fuel of the district, which, as well as the water supply, is still sufficient for mining purposes. Generating the electricity from a neighbouring waterpower, the Eustis Mining Company employ electric power at their works, and are expected eventually to light their extensive mine by the same means.

Labour in the district has advanced somewhat in price since the earlier mining operations, but is still low as compared with the more recently established mining centres. Mine foremen receive about $2.50 per day, miners $1.50, and labourers, $1.25.

And if to these circumstances there be added the improved methods of smelting, and the altered demands of the modern market, especially for the by-products of the sulphuric acid industry, it will be readily seen that the question of copper mining in the Eastern townships to-day is on an entirely different basis from that of forty years ago.

COPPER DEPOSITS OF THE EASTERN TOWNSHIPS.

The copper deposits of the Eastern townships are of three distinct classes. These are :

1st. Ores, chiefly chalcopyrite with small amounts of chalcocite and relatively unimportant amounts of carbonates, in pyrites. The deposits of this class occur in the porphyry-andesite schists, the oldest rocks of the region. They form lenticular bodies, apparently occupying crevices, or more likely having replaced the rock along lines of weakness produced in the course of the intense regional folding to which these rocks have been subjected. The gangue material when distinct from the country rock is generally quartz, though sometimes calcite.

2nd. Chalcopyrite, bornite, and chalcocite, with small amounts of carbonates, compose the deposits of the second class. These occur as irregular bodies in Cambro-Silurian sediments where the latter are invaded by certain intrusives. The gangue matter is largely calcite.

3rd. Chalcopyrite in pyrrhotite, with a little pyrite, forms the third class. The deposits of this class are situated along the contact of Cambro-Silurian strata with intrusive diabase. They are distinguished from the ore bodies of the second class, not only by the character of the ore and the presence of pyrrhotite, but also by the fact that the second group are generally extomorphic contact bodies, while the third are principally endomorphic features of the contact. Moreover the intrusives of the former are only dikes of comparatively small volume, but those of the latter class are large mountain-forming masses. The country rock of the second class of deposits, wherever they have shown any important dimensions, is limestone, with one possible exception, but in the third class it is an iron bearing slate in some cases, and other metamorphic rocks of the district in others.

1. Chalcopyrite and Pyrites Deposits.

In the Porphyry-Andesite Series.

The deposits of this class include the principal properties that were worked in the early development of the district, and all that are at present in operation. They comprise three principal groups:

(*a*) Some fifty mines and prospects, in the township of Ascot, and other townships near the city of Sherbrooke. Amongst these are the Eustis, Capelton, King, Suffield, Ascot and other less known properties.

(*b*) The series of deposits long known to extend through the townships of Sutton, St. Armand, Brome, Shefford, Ely, Melbourne, Cleveland, Shipton, Tingwick, Arthabaska, Chester, Ham, Wolfestown, Inverness and Leeds, as well as the divisions of the seigniory of St. Giles, known as the Handkerchief, and Ste. Marguerite, in the county of Lotbinière.

(*c*) Deposits in the little known district along the boundary line between the province of Quebec and the state of Maine, south and east of Lake Megantic.

It may be seen by reference to the accompanying map that these grounds are in the form of belts, which have a general northeasterly trend, and are approximately parallel. For convenience they may be designated as the Sutton, the Ascot, and the Lake Megantic belts.

In all cases the deposits of this class occur in, or in close association with, altered volcanic rocks, generally of the porphyry class. The country rock is always highly folded, and often twisted and contorted to a remarkable degree, and this deformation gives their shape to the ore deposits. In form the deposits are much flattened lenses, which lie in conformity with the foliation of the rock. They are arranged *en échelon*, generally along zones of extreme foliation. The individual lenses seldom exceed twenty or thirty, feet in width, and bodies of these dimensions would be from two hundred to three hundred feet in length, according to approximate generalization from observation of a considerable number of the smaller lenses, and from the experience of miners who have worked out many bodies. The third axis, that nearest the vertical, follows the dip of foliation. But its length relative to the other axes is not easy to ascertain, even

approximately, since it is only those lenses which lie wholly beneath the surface and which have been entirely worked out that can give data of any value, and such opportunities for observation are necessarily rare. Experienced miners soon agree that the dimension of these bodies along the dip is sometimes greater, at others less, than the horizontal axis, and some are of the opinion that it is generally greater.

The arrangement of the ore lenses *en échelon* is a matter of much importance in following the ore bodies. Thus in the Capelton district the miners have learned when a lens is exhausted to drift to the right, to find the next. That is, in proceeding along the strike towards the northeast, each succeeding lens appears on the southeast side of the previous one, *i.e.*, in the hanging wall, and in going towards the southwest the next ore body is to be looked for on the northwest, or in the foot wall. The dip here is from 40 to 70 degrees towards the southeast.

The ore bodies correspond in their arrangement with the order of the hills of the district, and with the general structure of the Appalachian Mountain system, in which each range when it terminates to the northward is succeeded by another lying to the east. It is this orographic feature which gives the Atlantic coast its general northeasterly trend.

Though rarely, the ore bodies, occasionally, cross the planes of foliation of the country rock. They then have the aspect of veins running slightly obliquely to the strike, or more rarely, to the dip of the enclosing rock. These vein-like massses are, however, of very limited extent, and are probably only the filling of local fractures between larger shearing planes. They are perhaps the better developed of the minor series of fracture joints.*

The walls of the ore bodies are not usually well defined, though one is often more definite than the other. The ore, which consists essentially of chalcopyrite in pyrite, grows poorer towards the edges of the bodies where there are no definite walls, until the proportion of ore in the country rock becomes so small as to be imperceptible. From the evidence at present available it can only be said that these ores were primarily brought in by the volcanics in which they are generally found ; that the subsequent folding

*J. B. Woodworth, Proceedings Boston Society of Natural History Vol. XVIII p. 397, 1896.

and shearing of these rocks developed planes of easier passage in which the subterranean waters, leaching out the metallic minerals from the rock, deposited them by replacement of the rock. The better defined wall on the side of the ore bodies may be due to the fact that the rock on one side of a shear plane being more highly fractured than on the other, as is often the case, the greater replacement would take place on the fissile side of the water bearing crevice. Then after the first film of ore had been deposited a protection is afforded by it for the rock face on which it is deposited and all further replacement is likely to be on the side of the more fractured rock. The foot wall is generally the one that is better defined.

The common occurrence of chalcopyrite in crevices within the pyrite, and as a thin layer upon a joint face, seems to indicate that the chalcopyrite was introduced later than the pyrite. But of this there is not enough known as yet to speak decisively. Actual crystal replacement has not yet been observed.

The average of a large number of assays of specimens from the south side of the Capelton hill, *i.e.* from the Eustis and Capelton mines, and other properties of the vicinity, made previous to 1886, showed the copper to range from 4 per cent to 5 per cent; sulphur, 38 per cent to 40 per cent; and approximately 1 oz. of silver to each unit of sulphur, with small amounts of gold.

A number of assays of recent date from the north side of the same hill, from the Suffield, King and other properties, give a lower percentage of sulphur, but higher metallic values, especially of silver, which here seems to vary without regard to the sulphur. As a very general statement the ores of this class of deposits may be said to carry 4 per cent of copper, 35 per cent sulphur, near the surface, and at greater depths to yield uniformly 3 per cent of copper, 40 per cent of sulphur, 3 oz. of silver, and small amounts of gold.

Gold, which does not seem to be present in appreciable amounts at lower levels, is often an important factor near the surface. Alluvial gold occurs in many of the streams which run over these copper bearing rocks, and the surface rocks yield gold in many parts. At a depth of a few feet from the surface most of such prospects have been abandoned, but in one or two notable instances the gold prospects have been developed into copper mines, through the copper increasing as the gold values decline.

Although it has not yet been found possible to get information sufficiently definite and accurate to make a satisfactory comparison of the

ores at different depths there appear to be slightly higher copper, and distinctly greater gold values, near the surface, than at a depth of a few hundred feet. This richer zone seems to be deeper but less well marked in the case of copper than of gold. The information available is, however, insufficient, as yet, to admit of safe generalization. At present it can only be said that there probably are such zones, that they are presumably due to secondary enrichment, and that the enrichment has taken place from above, and hence by means of descending waters. The evidences that both the iron and the copper sulphides were deposited in their present position after the foliation of the country rock began have been already noted.

The source of the copper and other metallic minerals seems undoubtedly to be the volcanic rocks. The principal deposits occur wholly within these rocks, smaller bodies, however, being not infrequently found along the contact of the volcanics with an overlying dolomite. In such cases the copper has evidently been deposited contemporaneously with the dolomite, which it more or less strongly impregnates for a distance of a few feet only from the volcanic rock.

It was recognized by Logan that the copper deposits were derived from the country rock. (Geology of Canada, 1863, pp. 734-5.) But, on the assumption that the country rock was of aqueous origin, they were regarded by him as an excellent example of sedimentary mineral deposits. Thus he wrote (Geology of Canada, 1863, p. 734 et seq.) "The evidence which has been presented in the descriptions of the copper deposits of the Quebec group, appears to show that the metal, like the iron, manganese, nickel and chrome, which so often accompany it throughout these rocks, was held in solution by the waters from which the sediments of the period were deposited. By the agency probably of organic matters it was reduced to the condition of a sulphuret and precipitated with the sediments, either in a finely divided state, or more frequently, in small nodules, or patches, which became interstratified with the limestones, the slates, the diorites, and the other rocks of the series. A subsequent action, probably contemporaneous with that which has metamorphosed and crystallized the rocks over a great part of their extent, dissolved out portions of the copper sulphurets from these beds and in certain cases deposited them with quartz and various spars in the fissures of the rocks; giving rise to the veins or courses which have been described.

"There appear to be, in this region, no facts to sustain the ancient notion of the connexion of metalliferous deposits with eruptive rocks which are absent from great portions of the district."

With the knowledge that the country rock is largely eruptive, and that eruptive rock is present at all the occurrences of copper of any probable importance in the district, the above opinion should evidently be reversed.

2. Chalcopyrite, Bornite, Chalcocite, &c.

Forming Contact Deposits between Cambro-Silurian Limestones and Certain Intrusives.

The ore bodies of the Acton district are the best known of the second class of copper deposits of the Eastern townships. The ores are chiefly sulphides, bornite becoming important, while it rarely, if ever, occurs in the deposits just described.

This group of ore bodies occurs in the vicinity of a series of dikes which extends from Roxton in the county of Shefford to Ste. Apollinaire in the county of Lotbinière, a distance of about one hundred miles. The principal occurrences known are at Roxton, Acton, Upton, Durham, Wickham, Drummondville, Nelson and St. Flavien. The greater part of all the ore bodies, and practically all of many of them, is found in the sedimentary rocks, generally Trenton limestone. But in several instances, notably at Roxton, Nelson and St. Flavien, copper occurs in the intrusive rock, an amygdaloidal diabase. At Upton a little native copper is also found.

At Acton, which has been by far the most important of this class of deposits, a large amount of high grade copper, much of it 30 per cent ore, was produced for several years. The sedimentary rocks at this mine are a magnesian limestone, overlying a black shale. Both are cut by dikes or an irregular intrusion of diabase, or some allied greenstone. The productive part of the deposit was found in the limestone, and when this was passed through the smaller amounts of ore in the shale made the work unremunerative.

In the township of Durham, some twelve miles south of Acton there occurs a body of these ores, the most southerly of the group. It is located near the southern edge of the limestone, which is here only fifty feet thick. The ore supply failed, just as at Acton, when the shaft reached the underlying shale.

Upton, six miles northwest of Acton, is the most remote of the deposits in that direction. Four different properties were at one time worked in this vicinity. None of the workings seem to have reached

a depth of one hundred feet. The ore occurs in irregular veins, or stringers in the limestone, which is generally crystalline. It is also finely disseminated through many parts of the limestone. A small amount of high grade ore was obtained by hand picking. No machinery for crushing or mining seems to have been used.

At Wickham, eleven miles northeast of Acton, copper was mined to a small extent. The geological conditions are similar to those at Upton, but the thickness of the limestone was not reached at either place.

At Drummondville, Nelson, and St. Flavien, farther to the northeast, the copper occurs in the intrusive rocks, which seem to form one or more dikes a quarter of a mile in width. The principal work was done at St. Flavien, where several shafts were sunk, and a depth of a hundred feet or more attained.

Although considerable development was carried on at all of the localities mentioned, as well as at some others, no permanent ores have resulted. The fact that the gangue material with the ores of this class of deposits is limestone should make them valuable to mix with the siliceous ores of the other deposits, where even a very low percentage of copper would add to the value of the limestone as a flux.

3. Chalcopyrite in Pyrrhotite.

Forming Contact Deposits between Intrusive Diabases of the Serpentine Series, and Sediments.

The ores of the third class of deposits are distinguished from the others by the predominance of pyrrhotite. Iron pyrites is also present, but chalcopyrite seems to be the only form in which copper occurs in these deposits. They are known to occur at various points along the serpentine belt, especially in the townships of Bolton, Potton, Brompton, Orford, Ham, and Garthby, and are liable to be found anywhere along the contact of the later eruptives of the serpentine area.

The Huntingdon mines, in the township of Bolton, have been the most extensively worked of any of this group. The ore forms a body some eight feet in width at the surface along the inner contact zone of a dike with clastic rocks. There are no structural or other features to suggest secondary concentration of the ore, or that the deposit is

other than an original segregation in the magma of the intrusive rock. The ore, of which large shipments were formerly made, is reported to have yielded an average of about 5 per cent copper.

The mine has not been in operation for some years. During the period of its most successful operation the nearest railway was twenty-four miles distant. At present a newly completed portion of the Orford Mountain railway passes within a few yards of the shafthouse.

The properties known as the Bolton and the Ives mines are situated about a mile and a half north of the Huntingdon, and near the village of Eastman, on the line of the Canadian Pacific railway. In the character of their ores, and their mode of occurrence, they are essentially similar to the last. They too are at present closed.

The Lake Memphremagog mine is situated on the northwest slope of Hogsback mountain, two miles from Tucks Landing, in the township of Potton. The development of this property consists at present of a vertical shaft eighty feet in depth, with an adit driven in to meet the shaft at a depth of fifty feet from the surface. The ore-body extends in length for three hundred feet in sight, and exposures a thousand feet apart are probably the continuation of the same deposit. In the adit, which is a cross-cut, one hundred and ten feet of ore are exposed, without the inner limit of the ore body having been reached. This ore varies in the amount of copper it carries from *one* to *nine* per cent. There are also small amounts of gold, generally enough to be appreciable.

In lot 21, range of Garthby, there is a deposit of a similar ore, which is apparently of important size. It is known as the Garthby, or Lac Coulombe mine. A shaft, said to be fifty feet deep, has been sunk, and apparently much of the output remains on the ground. The shaft seems to be sunk in solid ore. The surface stripping has not been sufficient to make it possible to estimate, even approximately, the size of the ore body.

II.

Igneous Rocks of the Eastern Townships of Quebec.

Outline.

1. Area defined.
2. Geography.
3. General geology.

4. Sketch of previous geological research.
5. Petrographical Province of the Eastern townships.
   Sub-provinces: (*a*) Copper bearing volcanics, and associated rocks.
   (*b*) Serpentines and diabases.
   (*c*) Granites.
   (*d*) Later dikes.
6. Petrographical Province of the Monteregian hills.

1.

That portion of the province of Quebec which has been affected by the Appalachian uplift lies wholly to the south of the St. Lawrence river. It comprises two somewhat distinct parts, the mountainous region of the Gaspé peninsula along the lower St. Lawrence, and the hilly country from the Chaudiere river to the International Boundary Line between the province of Quebec and the States of Maine, New Hampshire, and Vermont. The interval between the two portions is marked only by a subsidence in the Appalachian hills southeast of the city of Quebec.

The second of these two areas is commonly designated as the Eastern townships. Being less easily accessible, on account of its hilly character as well as its position, and also less desirable otherwise for settlement, this region was not surveyed until some thirty years after the cession of Canada to England. It was then, accordingly, divided into townships approximately square, and it was further subdivided into ranges and lots, according to the English method, instead of being formed into seigniories and parishes after the old French mode of survey.

The general trend of the hills of the Eastern townships is a northeasterly one, conforming to the direction of the Appalachian folding, the successive ridges growing higher as they are more remote from the St. Lawrence valley. The principal rivers, such as the Yamaska, St. Francis, Nicolet, Beçancour and Chaudière, cross these hills about at right angles to their course, and drain the region into the St. Lawrence.

2.

The tributaries of these rivers, however, take their direction from the Appalachian folds and generally flow in either northeast or south-

west courses. The tributaries are, therefore, subsequent to the Appalachian hills, while the main rivers are either antecedent to the later stages of that uplift or have been superposed on the older rocks by the extensive denudations of the region. Hence the tributaries are commonly much younger than the main rivers. From these facts, and also since the course of chief glacial action has been parallel to the valleys of the principal rivers and transverse to the tributaries, it results that many of the latter empty into the former by falls and rapids. The water which these furnish has given rise to several manufacturing centres, as the city of Sherbrooke where the Magog falls into the St. Francis, and the town of Windsor Mills at the junction of the Ouatopekah with the same river. The principal rivers thus give cross sections of the region, while the tributaries usually afford much less information regarding the underlying rock.

3.

With the exception of a few small outliers of Devonian the sedimentary rocks of the Eastern townships are now considered to be Pre-Silurian in age. Silurian strata occur a short distance to the north of the district in question, and small outliers may be found within it, but thus far none such have been definitely determined. To the Cambro-Silurian have been assigned certain of the limestones, the calcareous and ferruginous slates; to the Cambrian, part of the quartzites, greywacké, and the clay slates; while similar rocks, with the exception of the clay slates, are referred to Pre-Cambrian, as well as the large areas of slates that are characterized by the presence of chlorite and epidote.

Igneous rocks are found to underlie the earliest sediments, and to be intercalated amongst them, and to be intrusive through even the latest. Altered volcanics of both acid and basic types are the oldest; while closely associated with them are large areas of stratified rock, which are thought to be in part, at least, much altered tuffs. Serpentines occur amongst the earliest sediments, and probably also cut others of somewhat later age. The diabases and later gabbro-diorites, which are closely associated with the serpentines in position, as well as the granites which lie to the southeast of the Appalachian ridges, and the syenitic rocks of the Monteregian hills to the northwest, are later in age than any of the sediments. Still later than these are the dikes of camptonite, diabase and bostonite, which cut all of the rocks

already mentioned, and are themselves little altered in character or disturbed in position.

Extreme metamorphism has obscured or totally obliterated much of the fossil evidence which the sedimentary rocks might otherwise have furnished, while such fossil evidence as there is is rendered less useful for precise correlation by the peculiar conditions under which these sediments have probably been deposited. They have accordingly been designated in geological nomenclature as the Quebec group.*

4.

The group of rocks thus named by Logan and Billings was considered by them to be equivalent to the Calciferous and Chazy formations in part. Subsequently, however, Selwyn and Ells distinguished within the area assigned to the Quebec group the measures now mapped as Pre-Cambrian, showed much of the supposed Silurian to be Cambro-Silurian and classed the greater part of the remaining rocks as Cambrian.

The Pre-Cambrian comprises three main ridges which are the principal physiographic features of the Eastern townships, viz.: the Sutton Mountain, the Stoke Mountain and the Boundary Line hills. These ridges, which are roughly parallel, run in a northeasterly course as determined by the Appalachian folding and are themselves about twenty-five miles apart between the St. Francis and the Chaudière rivers. The rocks composing them were, in the first investigations of the Geological Survey under Sir W.E. Logan and Dr. T. S. Hunt, named argillites, sandstones, chloritic and nacreous schists and slates. In stratigraphical arrangement these ridges were supposed to be synclinal troughs, which had resisted denudation better than the intervening strata.

This view was first questioned by Hunt on stratigraphical grounds, and later by Selwyn, both on stratigraphical and lithological evidence. Dr. Selwyn reached the conclusion that these folded ridges are anticlines, not synclines, and held that the rocks composing them were older than the Quebec group and consequently formed no part of it. The results of the subsequent investigation by Dr. Ells substantiated this view.

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*Sir W. E. Logan, Geology of Canada, 1863, et aliter.

The first igneous rocks recognized in the Eastern townships were the granites of Stanstead and Megantic, the syenitic rocks of the Monteregian hills, Brome and Shefford, and the gabbro-diorites of Brompton, Orford and Ham. These are described at some length in the Geology of Canada, 1863, and have been previously discussed by Hunt.

Both Hunt and Logan regarded the serpentines as altered sediments and correlated them stratigraphically with the dolomites, in view of their magnesian contents. Dr. Selwyn seems to have been the first to point out the probable origin of the serpentines, and also suggested that the stratigraphical questions then under discussion were complicated by the fact that some of the other highly metamorphosed rocks were in reality disguised volcanics. A suite of specimens of doubtful rocks submitted by him to Dr. F. D. Adams, (Annual Report, G.S.C., 1880-81-82) proved the serpentines to be altered igneous rocks generally of the peridotite class, the so-called diorites to be diabases and allied rocks, and some of the other highly altered rocks of the region to be of sedimentary origin.

The re-examination of the areal geology of the district which was necessitated by this information, was entrusted to Dr. R. W. Ells, the results of whose investigations appear in the Annual reports of the years 1886, 1887 and 1894, and in the maps which accompany them.

In these maps the crystalline belts of Sutton and Stoke mountains are represented as Pre-Cambrian in age, and an area along the International Boundary Line is included in the same horizon. The sediments intervening are assigned to the Cambrian and Cambro-Silurian with the exception of some very minor areas which, as has been said, were found to have been occupied with remnants of Devonian and possibly of Silurian measures. The serpentines are included with the igneous rocks and the occurrences of 'basic eruptives' are shown to be more numerous than appeared in the earlier maps. The great body of the Pre-Cambrian, however, remained amongst the sedimentary rocks.

In addition to the accounts of these investigations a few independent papers have been published on this region.

In 1876 Sir J. Wm. Dawson discussed the mode of entombment of certain fossils, referring especially to localities in the Eastern townships. Some of the occurrences of fossils thus mentioned are of essential importance to this investigation.

In 1879 Dr. T. Sterry Hunt in the American Geologist discussed the structure of the region under the title 'The Quebec Group in Geology.'

In 1882 in an address before the Royal Society of Canada Dr. A. R. C. Selwyn first outlined his views of the structure and general lithology of the Quebec Group. (Trans. Roy. Soc. Can., 1882).

In 1902 the present writer showed that important parts of the Pre-Cambrian are composed of volcanic rocks which by their extreme alteration had been previously mistaken for sediments. Their relation to other occurrences of similar rocks in the Appalachian was suggested, and their place in the series described by the late G. H. Williams was pointed out.*

5.

(*a.*) Copper Bearing Volcanics.—(Pre-Cambrian.)

The physiographic structure of the Eastern townships, it has been said, depends on three ridges of Pre-Cambrian rock, which are in the form of rather narrow belts about twenty-five miles apart, running parallel to the axes of the Appalachian mountains. These ridges which rise above the intervening sediments and later intrusives are the crests of once buried mountain ranges, now partially uncovered. Outlying remnants of sedimentary rock are still quite frequently found within these belts.

One of the belts appears for only a relatively short distance along the boundary line between the province of Quebec and the State of Maine. It occurs in the townships of Emberton, Chesham, Clinton, Woburn, Ditchfield and Spalding. From its proximity to the lake of that name it may be designated the Lake Megantic area.

The second crosses the St. Francis river between the city of Sherbrooke and the village of Lennoxville, and is commonly referred to as the Ascot or Stoke Mountain belt. It may be traced from the foot of Owls Head mountain and Lake Memphramagog through parts of the townships of Stanstead, Hatley, Ascot, Ascot Corner, Stoke, Dudswell, Weedon and Stratford. The similar rock at the Gilbert River gold mines, in the seigniory of De Lery, on the east side of the Chaudière river, undoubtedly belongs to this belt.

* Transactions of the Canadian Mining Institute, Montreal, March 2, 1902. American Journal of Science, July, 1902.

The third of these belts, which crosses the St. Francis river near the town of Richmond twenty-five miles northwest of the last, is generally known as the Sutton Mountain belt. This is the largest and longest of the three as far as is at present known. While the Stoke belt is nowhere more than five miles in width, that of Sutton is quite twenty miles wide at the Vermont boundary line. It has a considerable development in the counties of Brome, Shefford, Richmond, Wolfe, Arthabaska, Megantic, Beauce, Dorchester, and probably extends also into Bellechasse and Montmagny, that is, to a point at least one hundred and forty miles from the boundary of the State of Vermont.

The rocks of the Sutton Mountain area were described by Logan, ('Geology of Canada,' p. 246,) as 'chloritic micaceous and epidotic rocks. Towards the province line,' he continues, 'these are of a slaty character and various shades of colour, from dark bluish-green or blackish-green to ash-grey. The green bands are more abundant than the grey, and both have occasionally a talcoid lustre. The grey bands appear to derive their colour from a large amount of very fine grains of quartz which are uniformly mixed with chlorite. These beds often contain certain nodules of white granular quartz, and crystalline pistachio-green epidote sometimes several inches in diameter, and frequently elongated in parallel directions. The two minerals are often in separate nodules, but as often are intermixed; in the latter case the epidote is generally within the quartz. In the grey bands fine blackish-green lines of chlorite often run parallel to one another, but these are contorted by the nodules of quartz and epidote, with which orthoclase feldspar is sometimes associated. 'Radiated actinolite often occurs in the rocks, together with asbestus in short parallel veins which are found cutting the epidote in the direction in which the nodules are elongated, and occasionally between the layers of slate. Crystals of specular and magnetic oxide of iron are abundant in the chloritic and epidotic bands, the magnetic species being more frequent where the chloritic prevails.'

'Near the St. Francis nodules of an epidotic character are richly disseminated through the chief part of these chloritic strata, some of the nodules being six, eight and even ten inches in diameter. Some of the bands hold small portions of finely granular quartz which occasionally swell into beds of white quartzite of some importance, while many of the strata assume the aspect of fine quartzose conglomerates, or coarse sandstones with a chloritic base."

Regarding the rocks of the Stoke belt, Logan writes (Geology of Canada, p. 252), "The rocks of this group here at the base of Owls Head mountain, branching off from a range of hills which come up from Vermont into Canada, take a northeasterly direction, and crossing Memphramagog lake run from the township of Stanstead through Stoke to Weedon, and constitute the Stoke mountains, which are bounded on each side by more recent strata just mentioned. The average breadth occupied by the Quebec group in these hills seldom exceeds two or three miles, except in Ascot and Stoke. On the St. Francis, in the former township, through the influence of these undulations, the Quebec rocks have a transverse measure of seven miles extending from the vicinity of Lennoxville to the northwest corner of the township, and in Stoke they present two parallel ranges included in a breadth of about five miles."

"In this range of hills the strata consist chiefly of chloritic rocks in harder and softer bands, the softer and more schistose constituting chlorite slates, while the harder may be termed chloritic sandstones. With these are associated micaceous and nacreous slates often presenting a very quartzose character, and thin layers of agalmatolite of a somewhat fibrous texture are sometimes met with. Some of the micaceous and nacreous slates are very fine grained, and on the south side of the range afford excellent whetstones, and hones. Many of the whetstone beds appear to be micaceous slates passing into argillite. Some bands of the slate are studded with chloritoid, and in Sherbrooke they enclose a bed of blood-red jasper, passing into a siliceous, red hematite, and another of a somewhat siliceous conglomerate."

"In the same neighbourhood the nacreous slates are marked by the occurrence of copper pyrites, containing a little gold and silver, in a gangue of white quartz running with the stratification. The chloritic slates are often marked by iron and copper pyrites; and on Haskell hill, on lot 8 of range VIII of Ascot, a band of slate five feet wide holds such a quantity of copper ore as to give promise of a profitable mine."

Selwyn pointed out that slates might be volcanic, as well as sedimentary, but subsequent reports added nothing to the lithologic description of these rocks.

The rocks of these belts consist of two parts, one of which is stratified, and the other unstratified. The latter is a volcanic rock, finely crystalline, and of both acid and basic phases. Quartz porphyry

and andesite, or diabase, would originally have been the extreme types. Some of basic phases are altered to serpentine, and all have been highly metamorphosed. It is only by very detailed field study, together with microscopic examination, that the volcanic character of some of these rocks has been ascertained.

Associated with these are stratified rocks of similar material, but which have an original clastic structure. Part contains bands of nearly pure chlorite, abundant quartz veins, and much iron ore. These are thought to be stratified tuffs, while other rocks, generally more siliceous, as chloritic sandstones and graywackés, are probably true sediments.

Although highly altered the volcanics of this series still show their original characters in localities in which the deformation has been least. The acid phase of the rock is largely a quartz porphyry. A specimen from the hanging wall of the Silver Star mine at Suffield is light grey in colour, and on the weathered surface the quartz phenocrysts are quite conspicuous. Owing to the bleaching of the base the rock has commonly been mistaken for quartzite, or a species of sandstone. The following is an analysis by Mr. M. F. Connor, B. A. Sc., Geological Survey of Canada, of a specimen of the essentially similar rock from the quarry at Sherbrooke, which furnishes road metal for the streets of that city:

Analysis.

SiO_2	70.37
TiO_2	·17
Al_2O_3	11.27
Fe_2O_3	.80
FeO	2.58
MgO	2.03
CaO	2.31
Na_2O	2.63
K_2O	1.86
CO_2	3.60
H_2O	1.96
	99,58

In the thin section it is found to be a porphyritic rock with a finely crystalline base, which contains phenocrysts of quartz and feldspar. The latter are both orthoclase, and plagioclase, the orthoclase being more abundant.

Small rod-like bodies of colourless mica are present in the rock, as well as irregular areas of a rhombohedral carbonate which is apparently dolomite.

Near Lennoxville, on the line of the Canadian Pacific railway, the rock becomes a granite porphyry, differing from the rock just described chiefly in the more advanced character of its crystallization. Farther eastward, where this belt is somewhat wider, the central portion becomes still more coarsely crystalline, and passes from quartz porphyry at the margin to granite porphyry, and finally to a porphyritic granite towards the interior. The latter is the rock of Bald peak, and of other principal hills of the central portion of the Stoke Mountain area, as well as a part of the Pre-Cambrian of Weedon. The basic portion is less well preserved, and its original character cannot be so precisely determined, as there are probably no original bisilicates now present. The decomposition products and traces of the original structure indicate that the rock had, in some cases at least, the character of diabase, while in others it was probably a porphyrite or andesite, rich in ferromagnesian constituents. Areas of serpentine which pass by sharp transition into hornblende porphyrite are occasionally found within the district occupied by this rock. While the alteration to serpentine seems to be complete, no part of the original rock being left, the serpentine has a somewhat different appearance from that derived from the olivine-rich rocks of the larger serpentine areas of the adjoining district. It is distinguished by the 'grating,' or 'bar' structure of serpentine derived from hornblende, or augite, instead of the 'mesh' forms resulting from the alteration of olivine. Small seams of asbestus occur in the serpentine, but although several of the areas have been prospected, no important deposit of tbat mineral seems to have been found in them.

The acid and the basic phases of these volcanics are not, however, products of separate irruptions, but are due to sharply defined magmatic differentiation. This is well shown in several of the streams that drain the southern part of Stoke mountain—notably on Rowe brook. The rocks may be considered as products of a single flow, or of one flow for each belt. In the Sutton belt, and so far as is known in the Lake Megnatic area also, there is evidence of no later volcanic action. In the Stoke belt, however, later dikes occur somewhat frequently, but they are chiefly of the camptonite and diabase classes. They cut the adjacent Trenton sediments, and so belong to a series of rocks to be described later, rather than to those of the present class, as they are not of Pre-Cambrian age.

The Pre-Cambrian volcanics are apparently closely related to those of South mountain, Pennsylvania, and other known localities to the southward and form a link of the more westerly of the two chains of

early volcanics that were described by the late G. H. Williams in the 'Journal of Geology,' Jan., Feb., 1894; (See also Ancient Volcanics of South Mountain, by F. Bascom, Bull. U.S.G.S., No. 136).

Possible Pre-Cambrian Sediments.—Of the stratified rocks in the metamorphic belt which are most closely associated with these volcanics, the extremely chloritic portions are probably ancient tuff beds, or at least are composed of fragmental volcanic material, and so are pyroclastic rocks. In the present degree of alteration they do not differ essentially from certain portions of basic rocks just described. Besides these are siliceous rocks, quartzites, greywackés and chloritic sandstones, which are possibly true sediments. With these are frequent beds of dolomite, the origin of which seems a matter of doubt. The rock is frequently found resting upon a basic trap, filling pit holes and interstices within it, and enclosing fragments of it. In other cases the rock passes by a rather gradual transition into a quartzose dolomite in masses of considerable extent. At the Eustis mine the portion of the country rock known to the miners as the 'green rock' is of this type. Even in the thin sections small areas of dolomite appear sometimes enclosing small quartz crystals and indicating the secondary nature of the dolomite.

Certain of the micaceous chloritic slates also contain sufficient dolomite to cause a slight effervescence by hydrochloric acid, when heated.

Along the St. Francis river the Sutton belt is some seven miles in its extreme width including nearly two miles of recognized Trenton measures within it. A detailed study shows the volcanics at the base with dolomite, quartzite and grey mica schist, in ascending order. Within the dolomite are certain peculiar inclusions of a bluish grey limestone which have been largely crystallized by intense regional metamorphism. One of these inclusions, however, contains fossil evidence of its Calciferous-Chazy age. It is, therefore, demonstrated that in this part, at least, the Sutton Mountain belt contains no Pre-Cambrian clastics.

As it thus seems certain that the Sutton series contains no Pre-Cambrian clastics in the vicinity of the St. Francis river, it is consequently possible, if not probable, that all the clastic rocks of this series throughout the district are, as in this section, altered members of the Quebec group.

The volcanics are the oldest rocks in this region, and from their lithologic resemblance to the Pre-Cambrian rocks of Pennsylvania and

other parts of the Appalachians, they are thought to be of that age. There is as yet no direct proof of this, but the available evidence leaves little room for doubt.

The overlying sediments are always much altered. In some cases the alteration would seem to indicate that these sediments are older than the comparatively unaltered rocks of the basins between the metamorphic ridges, but in other cases they can be traced continuously to rocks of undoubted Cambro-Silurian age. While the different degrees of alteration may in all cases be due to differences of position, or of susceptibility to metamorphism of the various rocks, it is not necessarily the case. Accordingly the question of the existence of Pre-Cambrian sediments in the Eastern townships must yet remain an open one.

(*b.*) Serpentines, diabases, etc.

A little to the east of the Sutton ridge, and parallel to it, there is a series of irregular hills which are intrusive through most of the other rocks of the region, generally Palæozoic sediments. They occur notably in the counties of Brome, Sherbrooke, Richmond, Wolfe, Megantic, and probably Dorchester, and are likewise known to reappear in the Gaspe highlands. Amongst them are the Bolton mountain, Owls Head, Orford, Ham and Adstock mountains. The rocks composing them are serpentines, diabase, gabbro-diorites with frequent or smaller masses of hornblende granite, and occasionally much smaller bodies of porphyrite. Of these rocks the serpentine seems to be in all cases the oldest, being cut by intrusions of the other, and possibly it is older than the Palæozoic sediments. The diabases and gabbro-diorites which are phases of the same magma form the greater part of all these hills. They are later in age than the serpentines through which they are commonly intrusive. The hornblende granite in some instances is distinctly intruded through the serpentines, but in one case at least, the Big Ham mountain, it seems unmistakeably to have been differentiated from the parent magma of that rock in situ.

The porphyrite is of limited occurrence; at Shipton Pinnacle, where it is best seen, it seems to cut the serpentine. It generally occurs as the matrix of a band of breccia, seldom exceeding 300 yards in width, that is frequently found along the southern edge of the serpentine belt. As far as it has been studied it seems to be a quartzless porphyrite containing a little hornblende as the only ferro-magnesian constituent.

Mount Orford (2860 feet) is the best known, as well as the largest, of the gabbro-diorite and diabase hills. It has an area of not less than

twenty square miles and an average height above the surrounding country of one thousand feet. It comprises two main divisions which give the following cross section measured westward along the line of the Canadian Pacific railway near Miletta : diabase or gabbro-diorite, 7837 feet, greywacké 165 ft., serpentine 577 feet, sandstone 82 feet, serpentine 1567 feet. This section is bounded by sedimentary rocks on either side. The rock of the first and greater mass is a uniform green colour, and shows grey grains on a freshly broken surface. Quartz veins are common and the joint plane and seams are often studded with small quartz crystals. Patches of epidote sometimes as much as a foot in diameter are numerous. The texture of the rock becomes finer towards the outer edge, and also towards the top of the mountain, where the cooling of the igneous mass has taken place more rapidly. In the thin section, this rock, which is exceedingly altered, shows plagioclase feldspar with aggregates of pyroxenic decomposition products, whose relation to one another indicates that the rock has had the structure of a diabase. In the coarser rocks of the central part of the mountain the mineral olivine appears. The rock has the mineral composition of diorite, but the hornblende is secondary and the rock therefore becomes a gabbro-diorite. The two rocks are apparently differentiation products of a single volcanic output.*

Analyses by Hunt (Rep. Geo. Sur. Can., 1853) show the composition of the altered gabbro-diorite and diabase mass, under the head of diorites, to be as follows:—

—	I.	II.	III.
SiO_2	63.40	63.60	63.43
Al_2O_3	12.70	14.20	14.20
FeO	4.23	1.92	1.54
MgO	3.37	6.84	2.35
Ca_2O	7.50	4.37	5.51
K_2O	.13	5.09	2.19
Na_2O	7.95	4.13	3.49
H_2O	.40	.70	1.65
			.87
	99.68	100.85	99.80

I. Diorite, Brompton lake, Orford, Range XVI, Lot 2.
II. Diorite, St. François de Beauce.
III. Grano-diorite, Butte co., Lassen peak, California.

Owls Head (2,465 feet) is situated on the west side of Lake Memphramagog, sixteen miles south of Mount Orford, which stands at

*J. A. Dresser, American Geologist, January, 1901.

the northern end of the same lake. The level of this lake is about six hundred and eighty-two feet above the sea.

The rock at the eastern base along the lake shore is a common basic phase of the Pre-Cambrian volcanics. On the west side the adjacent rocks are sedimentary. Between these the mass of the mountain has been intruded. It consists, as far as yet known, of extremely altered diabase which was first determined by Dr. Adams.

Sugar Loaf, the name by which a continuation of the Owls Head mass towards Orford is generally known, has been also shown by Dr. Adams to be similar in composition. (Rept. Geol. Sur. Can, 1880-1-2, Part A, appended.)

Besides Orford, Owls Head and Sugar Loaf, there are several hills along this line, presumably similar in character. These are Hogsback, between the two mountains last mentioned, Hawk and Bear mountains at the south of Owls Head, and Carbuncle and other hills at the north of Orford. So far as known these hills are similar to Orford and Owls Head in general structure as well as in the character of the rocks composing them. Fifty miles to the northeast from Orford, Big Ham mountain appears as the next prominent point along the serpentine belt, although that belt is almost continuous throughout that distance. The mountain rises fourteen hundred feet above the neighbouring land, or twenty-four hundred feet above mean sea level.

This mountain, as far as known, is a mass of much altered diabase. Near the eastern edge of the summit the diabase passes into a rock intermediate between hornblende granite and diorite, which may be tentatively classed as a grano-diorite. The transition is a rather sharp one, a distance of only a few yards separating typical specimens of the two rocks. The grano-diorite seems to form only a small body, and is probably the residual filling of the neck of the volcano which gave rise to the mass of the mountain.

Moose mountain, in the township of Cranbourne, beyond the northeastern limit of this map, is thought to belong to this series, although there is not much definite evidence concerning it yet available. A specimen from a spur of the mountain in the township of Frampton is a porphyrite, a not uncommon marginal phase of these rocks, and, as Dr. Ells reports the mountain to be intrusive in its relation to the sediments of the district, it may apparently be safely correlated with the diabase series.

Rocks very similar to those of Orford have been described from Adstock mountain, and also from the township of Potton, by Dr. F. D. Adams (*op. cit.*) Dr. Adams found a specimen from the summit of Adstock to be a diabase, and one from another part of the same mountain to be a diorite, both being much altered rocks. Concerning the latter he writes: 'It is a rather coarsely crystalline, massive, and of a greyish-green colour, and is composed of hornblende and plagioclase. The hornblende is green, or, in some places, brownish in colour, and is distinctly plechroic. . . . . It is often twinned. Much of the hornblende is decomposed to chlorite. In many cases the alteration appears to pass through an intermediate stage in which the hornblende assumes a very finely fibrous appearance. The fibres are generally approximately parallel, but do not as a general rule extinguish simultaneously. Individual fibres can often be seen to have an extinction inclined at a small angle to their longer axes. Some of these fibrous grains show a distinct biaxial figure. The plagioclase is dull from incipient decomposition but generally shows well defined polysynthetic twins, of which two sets are frequently present crossing one another. Although the two minerals have interfered with each other in crystallizing, both show good crystal forms. The feldspar is perhaps upon the whole the better crystallized of the two. The fibrous hornblende is found everywhere to be mixed with chlorite.'

The igneous origin of the serpentine was also first pointed out by Dr. Adams in the same publication. In a specimen from Melbourne the rock was found to be wholly reduced to serpentine, with the exception of a few grains of bastite or other mineral derived from rhombic pyroxene. In specimens from townships of Ham remnants of the primary olivine were also found.

The following analyses of serpentine of the Eastern townships are taken from the Geology of Canada, 1863.

	Orford.	Ham.	Bolton.
Silica	40·30	43·40	43·70
Magnesia	39·07	40·00	40·68
Nickel oxide	·26	.....	.....
Ferrous iron	7·02	3·60	3·51
Water	13·35	13·00	12·45
	100·00	100·00	100·34

Hornblende granite also occurs within this belt and is commonly intrusive through the serpentine. In other parts it seems to form an acid portion rather sharply differentiated from the magma of the parent rock of the serpentine. It has been described by Dr. Adams (*op. cit.*) as composed essentially of quartz, orthoclase, plagioclase, and hornblende, with a little titanic ore. It is also noted as showing a peculiar alteration of the hornblende. Where this mineral comes in contact with the quartz it displays a development of fibrous forms terminating in tufts of fine needles running into the quartz opposed to this marginal facies. The hornblende displays an ordinary even edge when in contact with the feldspar.

Dikes of this rock cutting the serpentine are considered by miners to be indicative of the occurrence of good asbestus. Whether the fracturing of the serpentine accompanying the intrusion of the granite has in any way furnished lines of weakness for the formation of asbestus veins has not yet been established.

Serpentine, apparently quite different in origin, occurs at several places within the porphyry-andesite belt already described. Here, within a distance of ten to twenty feet, well exposed rock may be traced from a quartz-porphyrite to serpentine carrying narrow veins of asbestus. Such occurrences are found in the townships of Ham and Leeds, and several other places within the volcanic belt. So far as yet known none of these are of large extent. That in Leeds is probably half a mile in length. The importance lies, however, in showing the range of magmatic differentiation, and consequently that the quartz-porphyry and serpentine are differentiates of a single original magma. As these are the extremes of chemical composition amongst the various rocks of the region the probability of all being differentiation products of a single primary magma is quite apparent.

(*c.*) Granites.

The granites of the Eastern townships occupy six principal areas, none of comparatively great extent. They form the granite masses of Stanstead, Hereford mountain, Big Megantic mountain, Little Megantic mountain, a small area on the east side of Lake Memphremagog, and another near Danville. There are probably numerous other small occurrences in this district, but it is noticeable that all of the granites lie to the south of the volcanics of the Sutton ridge.

None of the granite bodies have as yet been studied in detail, but all are believed to be intrusive through Lower Silurian sediments, and are thought to be of late Devonian age. The extensive quarries at

Stanstead have made the economic importance of that occurrence well known in the province of Quebec, where Stanstead granite is largely used for structural purposes. A specimen of this granite has been described by Dr. F. D. Adams, * and shown to consist essentially of orthoclase, quartz, and biotite, with accessory amounts of microcline and plagioclase, and secondary muscovite and epidote.

Of Hereford mountain nothing definite is known, save that its proximity to Stanstead and the generally similar appearance of the rock in the hand specimen suggest its close relation to that body. Its contact with the sediments is undoubtedly intrusive.

Even less is known of the Big, and the Little Megantic mountains. The material in the talus slopes of the former is a very acid granite.

The granite from Scotstown contains pyroxene, in addition to biotite and muscovite, as ferro-magnesian constituents.

The granite near Lake Memphremagog is also of the type of that of Stanstead.

Near Danville there is a small body of granite whose relation to the surrounding rocks has not been ascertained, nor has it received any detailed study. Biotite is the only dark constituent that is noticeable in the hand specimen. It is mentioned in the geology of Canada, (page 811), that it furnished part of the material for the Grand Trunk Railway bridge which crosses the Nicolet river in the vicinity.

The granite from the quarries at Stanstead shows an incipient cataclastic structure in the microscopic section, and in the mass, a somewhat distinct foliation, known by the quarrymen as the 'rift.' This structure is apparently due to dynamic metamorphism, and shows the granites to have shared in the folding of the Appalachian uplift, and consequently to have been intruded before that movement had entirely ceased. As dikes of adjacent granite masses cut Devonian (Lower Helderberg) strata on the shore of Lake Memphramagog, these intrusives are thought to be of late Devonian age.

(*d.*) Later Dikes.

A series of dikes of much later age than any of the rocks hitherto described is widely distributed throughout the region. They are comparatively fresh in composition and little disturbed in position. Camptonite, diabase and bostonite are the chief rock types represented amongst them.

* "Description of a Series of Thin Sections of Typical Rocks," by Frank D. Adams, Ph. D., F.G., Montreal, 1896.

A camptonite* at Richmond was found by the writer to consist of hornblende and plagioclase with magnetite and apatite. A little leucoxene and small aggregates of chlorite, serpentine and calcite indicate that some degree of decomposition has already begun in the rock.

The hornblende is brown in colour, and shows the extinction angle, to be as high as 17°.

This dike, which is about three feet wide, cuts lower Trenton limestone which has been greatly folded and distorted prior to the injection of the dike. One or two smaller dikes occur in the vicinity and a small hill nearby is thought to be underlain by the same igneous rock.

In the vicinity of Sherbrooke, twenty-five miles south of this locality, dikes are known to occur in several localities.

Near the line of the Canadian Pacific railway, in the northern outskirts of the village of Lennoxville, there is a camptonite very similar to the above.

It cuts both Pre-Cambrian volcanics and sedimentary slates of Trenton age.

At the Howard mine, Ascot, a dike of olivine diabase cuts Pre-Cambrian eruptives.

In a paper entitled 'Camptonites and other Intrusives about Lake Memphramagog' (Amer. Geo., July, 1895), Mr. V. F. Masters discusses a large number of dikes in Lake Memphramagog basin, distinguishing the granites, &c., connected with the intrusions off McGoon point already mentioned, from camptonites and allied dike rocks.

Between Roxton in the county of Shefford, and St. Nicholas in the county of Lotbinière, a distance of more than one hundred miles, there are several occurrences of intrusive rock in lower Palaeozoic strata. It is little known except in connexion with copper deposits in the region, which it seems invariably to accompany. It is found at Roxton, Acton, Upton, Durham, Wickham, Drummondville, Nelson, St. Flavien, St. Apollinaire and St. Nicholas, and seems to form a series of dikes in a comparatively narrow belt throughout this distance. The dikes vary in width from a few inches to a thousand feet or even more. and run parallel to the length of the belt in which they occur, *i.e.* in a northeast- southwesterly direction.

* A hornblende, lamprophyre dike at Richmond, P.Q., J. A. Dresser, Can. Rec. Sec., Jan., 1901.

At Roxton there is a light coloured intrusive of the trachyte class, but in most of these occurrences the volcanics are diabase, and are commonly amygdaloidal.

The largest exposures are at St. Flavien, Nelson and Drummondville. At St. Flavien the intrusion is nearly a quarter of a mile wide and appears to be a wide dike, extending for a distance of about a mile through the country. Similar rock appears at St. Apollinaire, seven miles distant.

These are the principal rock exposures. It is a level district covered with a heavy mantle of drift. The rock is amygdaloidal in many parts, the amygydules being most commonly filled with calcite; sometimes epidote and chlorite or quartz form the filling material. Copper frequently occurrs in this rock, and also at Roxton, Nelson and Wendover, near Drummondville. In other places, as at Acton, Upton and Wickham, the copper occurs in the extomorphic contact zone of the enclosing rock. The exposure at Nelson is smaller than that at St. Flavien, while that at Drummondville is apparently quite as large as the latter.

It is thus described by Logan, (Geo. of Can. 1863, p. 243,). "The greenish sandstones on the St. Francis are intersected by several dikes of diorite, the courses of which are in a general way down stream. The rock of the fall at Drummondville appears also to be a diorite and is of a grey or greenish colour; it probably belongs to the stratification and is not known to have any connexion with the dikes. It has a breath of about half a mile, and some parts are porphyritic from the presence of small crystals of light, greenish feldspar while others are amygdaloidal, holding small portions of a light and calc spar and occasional nodules of agate. Much of it bears the aspect of breccia, in which fragments of the diorite are held together by a close grained but highly crystalline calcareous cement, approaching in colour the general mass of the rock. The rock bears a resemblance to that of St. Flavien, of which it may be a continuation, and like it highly cupriferous.'

So far as yet examined, some half dozen specimens, the diorite of the above description proves to be a fine grained diabase. The diabase forms two bands crossing the St. Francis river here—one having a width of a quarter of a mile and the other of about fifty feet. The distance between them is rather more than a quarter of a mile and is occupied by very dark graphite limestone and greenish

grey sedimentary slates. What appears to be devitrified glass was found along the contact of the diabase and the latter rock. These rocks have been here mentioned under the head of 'Later Dikes,' because of their lithological similarity to known dikes, and the absence as yet of satisfactory proof that they are not themselves also of that class. This entire series offers an excellent field for an interesting and important detailed investigation.

6. Petrographical Province of the Monteregian hills.

This name, which has now gained general currency in geological nomenclature, was proposed by Dr. F. D. Adams, in 1903,* to designate a series of volcanic hills which crosses the St. Lawrence valley in the southwestern part of the Province of Quebec. These hills, which are eight in number, are of volcanic origin, either stocks or laccolites; they owe their present relief to differential erosion, and consequently are hills of the butte type.

Six of the eight hills form a nearly east and west line, standing about ten miles apart. In order from west to east they are Mount Royal, at the foot of which stands the city of Montreal (Mont Royal), Montarville or St. Bruno, Belœil or St. Hilaire, Rougemont, Yamaska and Shefford. The remaining stand at the south of this line, Brome being two and a half miles from Shefford, and Mount Johnson, six miles from Rougemont.

The lithological characters of these hills are such as to show them to be a distinct petrographical province, and to bear little, if any, relation to the rocks hitherto described in this article. In every hill there is a large development of essexite, which frequently passes into theralite, and in every one which has been studied in detail, an alkali-syenite such as nordmarkite, pulaskite, or nepheline-syenite. A list of the analyses thus far made from these rocks may serve to indicate their general character.

* Journal of Geology, vol. xi., No. 3, 'The Monteregian hills, a Canadian Petrographical Province.'

CHEMICAL ANALYSES OF TYPE ROCKS FROM THE MONTEREGIAN HILLS.

—	I	II	III	IV	V	VI	VII	VIII	IX
SiO_2	48·69	48·85	53·15	44·00	65·43	61·77	57·44	59·96	55·68
Al_2O_3	17·91	19·38	17·64	27·73	16·96	18·05	19·43	19·12	20·39
Fe_2O_3	3·09	4·29	3·10	2·36	1·55	1·77	1·69	1·8.	2·10
FeO	6·41	4·94	4·65	3·90	1·53	1·75	2·70	1·73	1·95
MgO	3·06	2·00	2·94	2·30	1·36	1·54	1·16	·65	·80
CaO	7·30	7·98	5·66	·94	·22	·89	2·66	2·24	1·92
Na_2O	5·95	5·44	5·00	2·30	5·95	6·83	6·48	6·98	9·18
K_2O	2·56	1·91	3·10	·45	5·36	5·21	4·28	4·91	5·34
FeO_2	2·71	2·47	1·52	1·90	·16	·74	1·97	·66	·60
P_2O_5	1·11	1·23	·65	·20	·02	·15	·60	·14	·06
MnO	·15	·19	·46	·08	·40	·08	·25	·49	·31
Cl	.....	.....	·07	.....	·04	.....	.....	.....	.....
H_2O	·95	·68	1·10	·80	·82	1·10	1·03	1·10	1·50
	99·36	100·02	99 84	100·01	99·78	99·97	99·69	100·17	99·83

I. Essexite (Essexose) Mt. Johnson.
II. " (Andose) "
III. " (Akerose) Shefford.
IV. " (Hessose) Brome.
V. Nordmarkite (Nordmarkose) Shefford
VI. Nordmarkite (Nordmarkose) Brome
VII. Pulaskite (Laurvikose) Mt. Johnson
VIII. " " Shefford.
IX. Tinguaite (Laurdalose) Brome.

A better knowledge of the igneous rocks of the Eastern townships, especially of the granites and diabases, is necessary before their genetic relations can be satisfactorily discussed. Yet certain general relations may now be deduced, and these conclusions, it is hoped, may be amplified and more precisely applied at some later time when all the rocks in question have become better known.

In general terms it may be said that those rocks of a definite district belong to the same province, (Dr. H. S. Washington, Journal of Geology, Vol. VI and VII, "Petrographic Province of Essex county, Mass."), whose phases in their nearest approach to one another do not differ more widely than the various differentiates of any single mass. Thus the porphyry-andesite series differs in its acid phase from the granites, as far as the latter are known, chiefly in degree of crystallization, not in composition. The more basic phase of the old volcanics, as has been shown, passes by differentiation in situ into a rock which has altered into serpentine. Hence the oldest group seems to form a connecting link between the granites on one hand and the diabases, serpentines, etc., on the other, and, accordingly, these three groups form part of a single petrographic province according to the definition quoted above. The Monteregian rocks appear more distinct

throughout the quite extensive range of variation within themselves. The individual hills differ from one another in a comparatively small degree. Also their distinctive characteristics are not yet found in any measure in the other groups of rocks mentioned. Should a detailed study of the granites show that within them are differentiated portions of more basic rocks, as, for example, should nepheline syenite be found in association with them, as it has been found in some cases in the Hastings district by Drs. Adams and Barlow, they would then appear as an acid extreme toward the east of the Monteregian series. But this has not been done, nor is there at present any valid reason for expecting such phenomena to be found. While the Monteregians appear at regular intervals at upwards of ten miles across the plain, no rocks of consanguineous types have been found to the east of Shefford mountain, although a careful examination has been made in that direction throughout the district wherever igneous rocks are known to occur. In the later dikes an indication of rocks of the Monteregian type exists. Though it is conceivable that almost any rock might be differentiated in small amounts from almost any magma, it is the most common relationship to find camptonite and bostonite types differentiated from highly alkaline magmas such as that of the Monteregian rocks. But the wide distribution of these dikes and their relatively small amount make them less important factors in considering the limits of the petrographic provinces. Thus while camptonites and bostonites may occur in many places to the east of the Sutton Mountain anticline, and diabase far to the west of it, as at Drummondville or St. Flavien, they rather illustrate what Prof. Pirrson, (Am. Jour. Sce., July, 1905), has recently called the "progression of rock types," than the extension of the boundary of either of the two distinct groups of rocks mentioned. It would, therefore, seem that the rocks of the Monteregian hills differ from the other rocks described in this article more widely than any of these from one another, that is, that the difference is a generic rather than a specific one. Hence the relation could be best defined as that of two contiguous provinces rather than as parts of one province even in the larger sense.

The study of the consanguinity of rocks tends toward the hypothesis that the interior of the earth may be regarded as containing a single magma of uniform character which, by process of differentiation within the crust of the earth, or during the process of extrusion, or during the process of cooling after extrusion, gives rise to all classes

of igneous rock. This is the extreme view of the origin of different species of igneous rocks by the process of differentiation. Partly in opposition to this is that known as the assimilation theory which supposes igneous rocks to owe many of their present differences to the older rocks with which they have come in contact, and by which they have been modified.* This theory could scarcely receive, under any circumstances, such wide application as that just assigned to the differentiation theory, namely, that all rocks have come from a universal common magma and are differentiated only by the rock material with which they come in contact. Nor could it be counted a directly essential character in large extrusive volcanic outputs. But in the consideration of intrusive rocks, where the invading lava may for long periods of time have been slowly taking in and dissolving the surrouding rock material, the process of magmatic stoping may have made the assimilation factor an important one in the modification of igneous rocks.

The Monteregian hills are all intrusive, and are comparatively small igneous masses; they have penetrated strata of different mineralogical and chemical composition. Thus the Hudson River mud stones, Trenton limestones, the graphitic limestone and black slates of the Farnham and Philipsburg series, as well as the quartz mica schists of the Sillery, have been penetrated by these rocks, without producing any material change in the rocks themselves, beyond a generally well marked endomorphic contact zone. Moreover, the sedimentary rocks through which the granites and the diabase series have been intruded are generally very similar to those surrounding the Monteregian hills; in fact, the Hudson River shales are the only rocks of the latter region not found in the former. Hence, it would seem that whatever the cause may be of the primary magmatic differentiation, the magma which gave rise to the Monteregian hills was primarily different from that which produced the other rocks discussed, with the partial exception already mentioned of the later dikes. In summarising it may be said that the rocks of southeastern Quebec present two petrographical provinces, and their differences are due to primary differentiation, i.e. to differences in the original magmas.

I. (a) Porphyry andesite series, extrusive and probably of Pre-Cambrian age.

* Dr. R. A. Daly, Am. Jour. Sci. On the Mechanics of Igneous Instrusions.

(b) The diabase serpentine group ranging in age from early Cambrian to late Silurian or Devonian.

(c) The granites, late Devonian age.

(d) Between these and the next province, in a measure bridging over the gap between them, or at least indicating that the extreme limit of each has been reached, are the later dikes.

II. The second province comprises properly only the unique group of the Monteregian hills.

ADDENDUM.

For the completion of the investigation which has been briefly outlined in this report a large amount of field and laboratory work is yet necessary, much of which has an economic importance that is not less than its value to pure science. The later dikes are very little known, and yet the occurrence of important deposits of copper in the northern part of the district occupied by them has been known for fifty years. The granites are a geologic unit concerning which we have very little knowledge, and of which correspondingly little use is made, while the pyrrhotites of the diabase series promise economic results, perhaps no less important than the asbestus and chromic iron deposits, which also await detailed scientific investigation.

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