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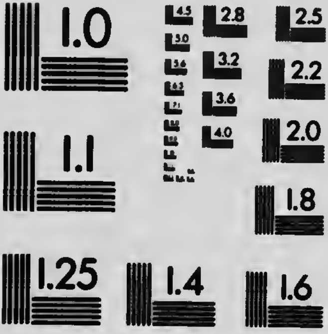

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DEPARTMENT OF MINES

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GEOLOGICAL SURVEY

WILLIAM MCINNES, DIRECTING GEOLOGIST.

MEMOIR 113

No. 96, GEOLOGICAL SERIES

Geology and Mineral Deposits of a Part of Amherst Township, Quebec

BY

M. E. Wilson

OTTAWA
J. DE LABROQUERIE TACHÉ
PRINTER TO THE KING'S MOST EXCELLENT MAJESTY
1919

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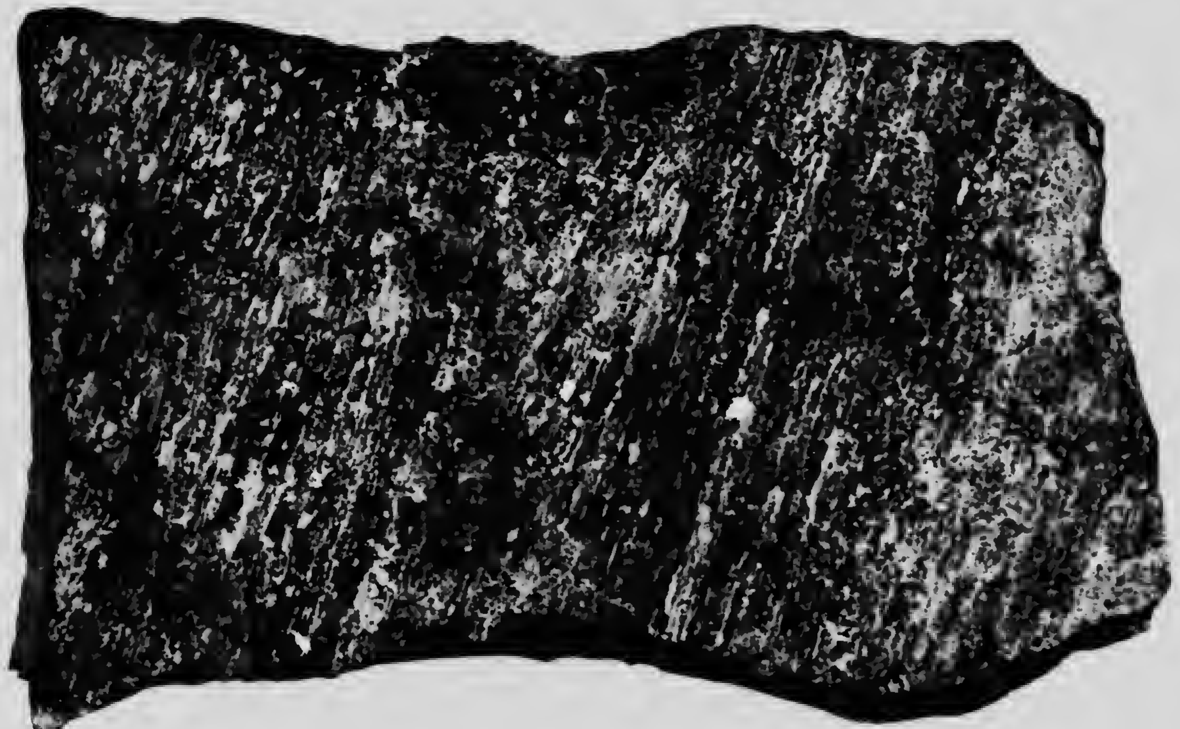
PLATE I.



Fragment from bed of kaolinic Grenville quartzite showing the vertical linearity of the quartz grains, lot 5, range VI, south, Amherst township, Quebec. (Page 23.)

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CANADA
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Hon. Martin Burrell, Minister; R. G. McConnell, Deputy Minister.

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CHAPTER I.

INTRODUCTION.

GENERAL STATEMENT AND ACKNOWLEDGMENTS.

Although deposits of the mineral kaolin, kaolinite, or china clay are known to occur in numerous localities in Canada[1], most of these occurrences are of small extent and hence of no commercial importance. Furthermore, since kaolin commonly occurs in such relationships as to indicate that it has been formed as a product of surface weathering and, throughout a large part of Canada, the products resulting from such alteration have been, for the most part, removed by the erosive action of the continental glaciers, it is probable that deposits of kaolin, on the whole, are less abundant in Canada than in parts of the world where Pleistocene continental glaciation did not occur. The presence of extensive deposits of kaolin near the village of St. Remi, in the southern part of Amherst township, Labelle county, Quebec, a locality well within the glaciated uplands of the Laurentian plateau, is, therefore, not only of considerable geological interest but of great importance to Canadian industries in which kaolin is used.

The field investigations, upon which the following report is based, with the exception of a re-examination of the kaolin deposits in July, 1918, were carried on in the latter part of the summer of 1916. This work included a study of the deposits of kaolin, an examination of a number of graphite occurrences on lots 15, 16, and 17, range VI, north, Amherst township, and the preparation of a geological map of the district, 12 square miles in area.

The writer wishes to express his indebtedness to Victor Dolmage and L. P. Gouin, both of whom assisted in the field work necessary for the preparation of the geological map which accompanies this report; and to J. C. Broderick, Managing Director of the Canadian China Clay Company, by whom every facility was afforded for the study of the kaolin deposits.

LOCATION AND MEANS OF ACCESS.

The St. Remi district, in which the kaolin deposits occur, is situated in the province of Quebec, approximately 30 miles north of the Ottawa river and almost equidistant from Montreal and Ottawa. It lies at the

[1] Rept. Roy. Com. on Mineral Resources of Ontario, p. 70; Ann. Rept. Ont. Bureau of Mines, vol. XIII, pt. 1, p. 60; Geol. Surv., Can., Dept of Mines, Mem. 74, 1915, p. 138; Ann. Rept. Ont. Bureau of Mines, vol. XXI, pt. 1, p. 193.

western terminus of the Huberdeau branch of the Canadian Northern railway and almost midway between St. Jovite on the Mont Laurier branch, and Calumet on the North Shore Branch, of the Canadian Pacific

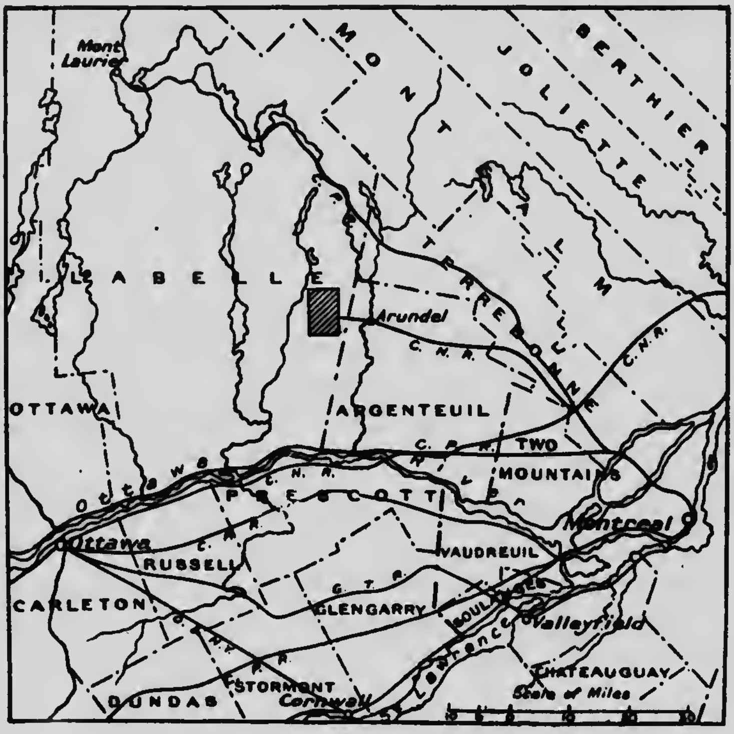

Figure 1. Index map showing position of area.

railway. It is, thus, most easily accessible by way of the Canadian Northern railway from Montfort Junction, but can also be reached by way of the Rouge River road from either Calumet or St. Jovite.

PREVIOUS WORK.

In the year 1862 Mr. James Low, assistant to Sir William Logan in the Grenville district, examined the geology along Maskinonge river, the principal western tributary of Rouge river, and in the course of this examination traversed the southwestern part of the territory afterwards surveyed as Amherst township.

In 1895 Mr. J. Obalski, late Superintendent of Mines for Quebec, visited the district for the purpose of examining a deposit of kaolin which had been newly discovered at that time, and in his report for that year stated that kaolin containing a large proportion of quartz had been found in the bottom of a well on lot 5, range VI, south, Amherst township.

In 1911 the kaolin deposits of the district were visited for the Geological Survey by F. Ries and J. Keele and were described by Mr. Ries in the Summary Report of the Geological Survey for that year, and by Mr. Keele in Memoir 64, " Preliminary report on the clay and shale deposits of the province of Quebec."

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CHAPTER II.

PHYSIOGRAPHY.

GENERAL STATEMENT.

The St. Remi district lies close to the border zone between the great Pre-Cambrian upland of northeastern Canada and the extensive lowland which forms the central part of the lower St. Lawrence basin. Thus, it exhibits most of the characteristic topographic features of the Laurentian highlands, but is distinguished from other parts of the Laurentian upland by greater dissection and by the presence of post-glacial marine clay and sand deposited in the bottoms of its major depressions.

For the purpose of topographic description the district falls naturally into four areas: (1) the St. Remi flat, (2) the Rockway flat, (3) the rocky uplands, and (4) the drift covered uplands.

ST. REMI FLAT.

The St. Remi flat occupies the bottom of a deep valley which extends in a southwesterly direction diagonally across range VI and adjacent portions of ranges A and B in Amherst township, and is a northern continuation of the wider flat which extends along Maskinonge river. It has an elevation of 701 feet above sea-level[1] and is underlain by silt, clay, and sand. The surface of the flat, or the whole, is uniform and plain-like, but is interrupted here and there by knobs and ridges of bedrock and glacial drift and by shallow basins occupied by marshy lakes (Plate II A). With the exception of a small area in the southwestern part of the district traversed by Maskinonge river, the drainage of the flat is effected entirely by Pike creek, a stream of considerable size originating in a series of lakes situated farther to the north outside the area examined. A well developed terrace between 15 and 20 feet in height has been formed on the east side of Pike creek in lots 1, 2, and 3, range VI, north and south, Amherst township.

Although marine shells or other positive evidence of the marine origin of the deposits underlying the St. Remi flat were not found in the district examined, the presence of marine clay and sand in adjoining districts at higher elevations[2] indicates that they represent material laid down during the Champlain marine submergence.

ROCKWAY FLAT.

The Rockway flat occupies an extensive area in the southeastern part of Amherst township and adjacent parts of Ponsonby township. It is similar in character to the St. Remi flat, but has a somewhat lower elevation (663 feet above sea-level at the village of Rockway)[3]. Only the northwestern part of the flat lies within the boundaries of the district described in this report.

[1] White, James, "Altitudes in Canada," p. 212, Commission of Conservation, Canada, 1915.
[2] 735 feet above sea-level northwest of Lachute.
[3] White, James, "Altitudes in Canada," p. 212, Commission of Conservation, Canada, 1915.

ROCKY UPLANDS.

The rocky uplands include the elevated rocky parts of the district and are characterized by a minutely rugged topography, numerous irregular lakes, precipitous water courses, and other features typically developed in the Canadian Laurentian highlands. In most localities these upland districts correspond approximately in form to the batholithic masses of granite or syenite which occur so abundantly in the Pre-Cambrian complex of the region, but in places they are underlain by the garnet gneiss member of the Grenville series or by pyroxenic gneiss belonging to the Buckingham series. The maximum elevation of the upland areas in the St. Remi district is approximately 1,300 feet above sea-level.

DRIFT COVERED UPLANDS.

The drift covered uplands include those areas in the district—generally intermediate in elevation between the rocky uplands and the marine flats—in which the bedrock surface is almost completely covered by glacial drift (Plate II A). The most extensive upland of this type occurs in the vicinity of the china clay deposits of the Canadian China Clay Company in the southern part of range VI, Amherst township. The drift covered area in this district has an average width of approximately half a mile and a length from north to south of 3 miles. It has an elevation ranging from 800 to 900 feet above sea-level.

CHAPTER III.

GENERAL GEOLOGY.

GENERAL STATEMENT.

The most abundant rocks in many localities throughout the Laurentian highlands of southeastern Ontario and Quebec belong to a group of highly metamorphosed sediments: crystalline limestone, garnet gneiss, and quartzite, constituting what is generally known as the Grenville series. This region is thus distinguished from other parts of the Canadian Pre-Cambrian upland by the presence of this series of sediments, and for that reason has been designated the Grenville Pre-Cambrian subprovince. The St. Remi district in Amherst township, Quebec, lies in the midst of this subprovince, and includes not only the rocks of the Grenville series but many of the other rock types commonly represented in the Grenville belt.

TABLE OF FORMATIONS.

The succession of formations present in the district, arranged in descending order, is as follows:

Quaternary	Champlain	Gravel, sand, and clay.
	Glacial	Boulder clay, gravel, and sand.
Late Pre-Cambrian		Diabase.
Early Pre-Cambrian		Granite-syenite gneiss.
		Metamorphic pyroxenite.
		Buckingham series:
		Pyroxenite (igneous).
		Gabbro.
		Pyroxene diorite.
		Pyroxene syenite.
		Grenville series:
		Quartzite.
		Garnet-gneiss.
		Crystalline limestone.

BASAL COMPLEX.

With the exception of the unconsolidated Quaternary deposits and a single dyke of diabase, all the rocks observed in the district mapped belong to those ancient Pre-Cambrian formations which because of their highly deformed or otherwise metamorphosed condition are commonly grouped together as the basal complex. The detailed succession of formations within this complex, as represented in eastern Ontario and the southern Laurentians of Quebec, has not yet been completely worked out, but the results of investigations in scattered localities seem to indicate that four principal groups of rock are represented, as follows: (1) a group of recrystallized marine sediments known as the Grenville series; (2) a group of igneous pyroxenic rocks—gabbro, anorthosite, pyroxene syenite, etc., intrusive into the Grenville series; (3) batholithic masses of granite and syenite intrusive into the rocks of groups 1 and 2; and (4) masses of diopside, scapolite, and other lime-silicate minerals known as "pyroxenite", formed by the contact action of rocks of groups 2 and 3 on the limestone member of the Grenville series.

GRENVILLE SERIES.

The oldest rocks observed to be present in the St. Remi district, as elsewhere throughout the Grenville Pre-Cambrian subprovince, belong to the Grenville series. This series of rocks is believed to have been originally laid down as alternating beds of shale, sandstone, and limestone similar in every respect to marine sedimentary formations laid down in later geological periods, but owing to the metamorphism to which they have been subjected, the limestone has been transformed to crystalline limestone, the shale to garnet gneiss, and the sandstone to vitreous quartzite.

Crystalline Limestone.

Distribution. Crystalline limestone was observed in two localities within the area included in the accompanying map, namely: on the slope of the upland area occurring at the east end of lot 5, range V, south, Amherst township; and in the district adjacent to the graphite deposits occurring in lots 15, 16, and 17, range VI, Amherst township.

Lithological Character. The Grenville limestone occurring in St. Remi district, in its typical outcrops consists of fragments and crumpled bands of rusty grey gneiss included in a matrix of medium to coarse-grained calcite in which grains of green pyroxene and flakes of graphite are abundantly disseminated. The rusty gneiss inclusions, when studied in thin sections under the microscope, were found to vary considerably in the different occurrences. In one thin section examined the rock consisted of granular quartz, orthoclase, microcline, and plagioclase (having the optical properties of $Ab_7 An_3$), throughout which a few grains of pale green pyroxene, titanite, and apatite were disseminated. In several other thin sections, however, the principal constituents were orthoclase, plagioclase, pyroxene, and scapolite; the less common constituents were titanite, apatite, pyrrhotite, and graphite. The first rock type thus had the composition of an aplite or pyroxene granite, whereas the other types were scapolitic pyroxene syenite. All of the inclusions are fine-grained but variable in texture, the individual mineral grains ranging from 0·1 mm. to 2 mm. in diameter. The limestone matrix in which the fragments and bands of pyroxene granite and syenite are enclosed was seen under the microscope to consist chiefly of grains of pyroxene and scapolite enclosed in a calcite matrix. The less common disseminated constituents were pyrite and graphite.

Garnet Gneiss.

Distribution. The garnet gneiss occurs partly in small lenses and bands, interlaminated with quartzite and pyroxene gneiss, and partly in more extensive masses, throughout which the other rocks of the basal complex have been more or less intimately intermingled. Occurrences of the first type are common in the areas indicated on the map in the central part of lots 4, 5, 6, and 7, range VI, south, and in lots 23, 24, and 25, ranges A and B, Amherst township. The areas of the second type lie along the western border of the area mapped. These include a large proportion of pyroxenic gneiss and granite-syenite gneiss, as well as intermediate types possibly the result of the interaction of these intrusions with garnet gneiss.

Lithological Character. The outstanding characteristic of the garnet gneiss as seen in the hand specimen or on the surface of its outcrops, is the heterogeneous appearance which it presents (Plate IIIA). This heterogeneity may arise in part from variations in texture, and in part from variations in composition, but chiefly from the occurrence of the individual minerals in aggregates. The principal mineral constituents generally visible in the rock are garnet, quartz, feldspar, mica, and pyrite, but the proportions of these constituents is exceedingly variable. Thus, in some thin sections of the rock examined quartz was entirely absent and orthoclase or orthoclase and plagioclase were the salic constituents, whereas in others orthoclase or plagioclase were subordinate in quantity and quartz was abundant. The garnet contained in the rock occurs as numerous, large, irregular grains, traversed by numerous fractures. The orthoclase is commonly filled with perthitic inclusions too minute for definite determination. They have a refractive index higher than the orthoclase, and in some sections are in the incipient stages of alteration, features which indicate that they are probably plagioclase. Plagioclase when present in the rock in individual grains usually exhibits the optical properties of andesine. The biotite is a light yellow to red brown variety and is generally abundant. It usually occurs in aggregates, but in one thin section was observed to lie in the interspaces between the feldspar grains. Sillimanite, which is generally a common constituent of the garnet-gneiss, was observed in only one of the thin sections prepared from specimens of garnet gneiss collected in the St. Remi district—namely that taken from the new shaft on lot 5, range VI, south, Amherst township.

Quartzite.

Distribution. The Grenville quartzite has its principal development in a north-south zone extending through the western part of range VI, south, Amherst township. In this locality, excavations through the drift have shown that it forms a continuous mass, approximately one-half mile in width and 3 miles in length.

Lithological Character. In those localities where the quartzite has not been granulated by deformation it presents a white, vitreous, massive appearance, very similar to vein quartz. Its bedded character is indicated in places by its interlamination with garnet gneiss and with beds containing a larger proportion of impurities than the normal quartzite. Under the microscope the rock is seen to consist mainly or entirely of irregular grains of quartz, averaging approximately three-quarters of a millimetre in diameter. In some thin sections a few flakes of pale yellow to red brown biotite were observed; in others, flakes of muscovite; and in one, plagioclase having the optical properties of andesine. The biotite and muscovite lie along the contacts of the quartz grains, a feature indicating that they have possibly been introduced into the quartz secondarily. In a few sections the quartz was observed to contain hair-like inclusions. As far as was observed, these did not have any definite orientation.

Structural Relations.

The outstanding structural features exhibited by the rocks of the Grenville series are the effects which apparently result where associated rocks of varying competency undergo intense deformation under extreme conditions of temperature and pressure. If a rock of low competency—such as limestone—into which dykes of granite or other igneous rocks have been intruded, or with which beds of quartzite or garnet gneiss are interstratified, were subjected to deformation under conditions of high temperature and pressure, it would seem probable that the associated dykes or beds of more competent rock would break up into fragments and become scattered through the limestone as inclusions. On the other hand, if garnet gneiss or quartzite with which beds of limestone are interstratified at intervals were similarly deformed, it is apparent that the less competent limestone member would tend to flow to those points where the pressure was least intense, and that a bed formerly uniformly continuous would become broken up into detached masses. All of the preceding processes were evidently in operation when the rocks of the Grenville series were deformed; for the crystalline limestone is filled with inclusions of other rocks, and occurs everywhere in detached, irregular masses rather than in continuous bands; and even the more competent quartzite and garnet gneiss in many places exhibit a similar phenomenon, the quartzite occurring as lenticular masses enclosed in the gneiss.

The intrusive relationships of the rocks of the Buckingham series, and the batholithic granite and syenite to the Grenville series is rather a matter of inference than direct observation, for dykes of the latter definitely intrusive into the Grenville series were not observed anywhere in the St. Remi district. Since, however, these are clearly igneous rock types, and the Grenville series is of sedimentary origin, it is inferred from the occurrence of the gabbro, pyroxene syenite, pyroxene diorite, and granite-syenite bands alternating with the Grenville sediments, from the metamorphism they appear to have effected in places, and from their occurrence as inclusions up to 50 feet or more in diameter in the limestone, that they have been intruded as sills, dykes, or lit par lit injections into the Grenville series, and that their intrusive relationships have since been obliterated by deformation.

The relationships of the Grenville series to the rocks which precede them, up to the present have not been observed anywhere within the Grenville subprovince. It is obvious that a floor upon which these sediments were deposited was at one time present in the region, but observations would seem to indicate that it is either not now exposed or has been obliterated by igneous intrusion and deformation.

Origin.

It is believed that the rocks of the Grenville series represent a group of marine sediments originally laid down as alternating beds of shale, sandstone, and limestone, and that as a consequence of the intense metamorphism to which the series has been subjected, the limestone has been transformed to crystalline limestone, the shale to garnet gneiss, and the sandstone to vitreous quartz. The reasons for these conclusions are: (1) the association of the rocks of the series as interstratified beds similar to the manner in which marine sedimentary deposits usually occur, and (2) chemical analysis of the garnet gneiss shows that this rock in every detail has the chemical composition of a shale, so that the three rock types, garnet gneiss, quartzite, and limestone have respectively the chemical composition of the three dominant members of the normal marine sedimentary series of the well sorted types.

BUCKINGHAM SERIES.

General Statement.

In most localities throughout the eastern part of the Grenville subprovince, m ses of gabbro, pyroxene-diorite, pyroxene-syenite, anorthosite, and related rocks occur, which although varying in composition from syenite or even granite to peridotite, have so many features in common as to indicate that they are genetically related to one another. The rocks of this group all have a granular texture, contain a pink to pale green monoclinic pyroxene as their most abundant ferromagnesian constituent, and, as far as their relationships have been observed, appear to be younger than the Grenville series and older than the batholithic intrusions of granite-syenite gneiss. In consideration of the wide extent of these rocks, their peculiar mineralogical composition, their evident genetic relationship to one another, and their probable approximate contemporaneity in age, they have been grouped together as the Buckingham series. In the St. Remi district the Buckingham series is represented almost entirely by an acidic gabbro, but outcrops of pyroxenite, pyroxene-diorite, pyroxene syenite, and pyroxene granite were also observed.

Distribution.

The rocks composing the Buckingham series are exposed in the St. Remi area partly in belts interbanded with garnet gneiss, and partly as scattered outcrops protruding through the marine flat that extends along Pil e creek and Maskinonge river. Occurrences of the first type were observed in a northeasterly trending belt from 1,000 to 2,000 feet wide, extending diagonally across the northwest corner of the area mapped, and in the central part of the ridge of garnet gneiss outcropping at the south end of lot 24, range A, Amherst township. The small scattered knobs occur at the north end of lots 24 and 25, range A, at the west end of lot 7, south, and lots 2 and 3, north, range V, and at the east end of lot 3, range IV, Amherst township.

Lithological Character.

Pyroxene Syenite. Rocks belonging to this class were observed in two outcrops, one adjoining the south side of the road leading west from St. Remi village on lot 3, range V, north, and the other adjoining Maskinonge river at the west end of lot 7, south, in the same range. It consists of orthoclase containing perthitic inclusions of plagioclase, pink pyroxene almost completely altered to olive-green amphibole, a few scattered flakes of red-brown mica, and disseminated grains of apatite and magnetite.

Pyroxene Diorite. The name pyroxene diorite has been applied to the rock composing the knobs outcropping west of Pike creek on lots 2 and 3, ranges IV and V, Amherst township. In the hand specimen this rock resembles the gabbro members of the series observed farther to the south, except that it contains a large proportion of feldspar and correspondingly less pyroxene. A thin section of the rock examined under the microscope was seen to consist chiefly of pale green to pink pyroxene and plagioclase (Ab_{71} An_{29}) but titanite, apatite, and magnetite were also present as disseminated grains.

Gabbro. The gabbro member of the Buckingham series represented in the St. Remi area is a medium to coarse-grained, massive to foliated rock, in which black pyroxene and a resinous looking feldspar are the most conspicuous constituents. When examined in thin sections, the rock was found to contain the following constituents: pyroxene, amphibole, plagioclase, biotite, apatite, and magnetite. The pyroxene is a red to pale green variety, having an extinction angle in sections parallel the optic plane of 35 degrees. It is generally more or less altered along the margin of the individual crystals to a compact, pale yellow to olive-green amphibole. The plagioclase possesses the optical properties corresponding to the composition Ab_{64} An_{36}, and hence might be designated an andesine-labradorite. In some thin sections the plagioclase was observed to contain a few perthitic inclusions of a colourless mineral with considerably lower refraction index, probably orthoclase. Biotite is not an abundant constituent of the rock, but a few flakes are generally present. These are pale yellow to red brown in colour, and in some sections were observed to be embedded in the pyroxene. The magnetite occurs as numerous, irregular grains scattered through the rock. It is probable that this is a titaniferous variety, similar in composition to the larger masses of this mineral present in the gabbro in many districts. The texture of the gabbro is seen under the microscope to vary in different localities, for in some thin sections the various mineral grains appear to be approximately uniform in size, whereas in others large crystals of pyroxene and feldspar occur embedded in a matrix of fine, granular feldspar. These relationships seem to indicate that the rock has been granulated in places.

Pyroxenite. Throughout the northern part of the zone of pyroxene gneiss, extending diagonally across the northwestern part of the area mapped, numerous scattered masses of coarse pyroxenite up to 50 feet or more in diameter are included in gabbro and constitute from 25 to 50 per cent of the whole. These are not sharply defined inclusions, but fade into the adjoining rock by a gradual decrease in the proportion of pyroxene present. In one locality, however, small dykes of gabbro were observed to intersect and to connect across the pyroxenite mass. Lithologically, the pyroxenite consists of closely compacted, coarse crystals of pyroxene up to 2 inches in diameter, the interspaces between which are filled with plagioclase. The rock thus is mineralogically similar to the gabbro, and differs from it merely in the relative abundance of the constituent mineral present. It seems evident, therefore, that the pyroxenite member of the

Buckingham series is genetically related to the gabbro member, and has been segregated from it by differentiation.

Other Related Types. In several localities a number of rocks containing pyroxene were observed, which are possibly either phases of the Buckingham series, or are intermediate types resulting from the interaction of the rocks of the Buckingham series with the garnetiferous member of the Grenville series. A fine grey gneiss in which garnets are sparsely disseminated is exposed on the face of the escarpment adjoining the west shore of Lavigne lake. When examined under the microscope, this rock was found to consist of numerous, angular grains of quartz, orthoclase, pale green to pink pyroxene similar to that contained in the gabbro of the Buckingham series, and a few disseminated grains of red garnet.

According to its mineralogical composition this rock is a garnetiferous pyroxene granite, and hence may represent another member of the Buckingham series. It might be possible, however, that it is merely the garnet gneiss member of the Grenville series, into which emanations derived from the gabbro of the Buckingham series have penetrated.

Another peculiar rock related to the Buckingham series occurs on the ridge of banded garnet gneiss (Plates IIIB and IV) that outcrops on the north shore of Lavigne lake. This rock under the microscope is seen to consist of pink pyroxene partly altered to olive green amphibole, red brown mica, labradorite, and numerous large, angular grains of red garnet. It thus differs from the normal gabbro of the Buckingham series merely in the presence of the garnet, and in the greater abundance of the mica present. It is possible that this garnetiferous type has been formed by the interaction of the gabbro member of the Buckingham series with garnet gneiss, but if such were the case, it might be presumed that the resulting rock type could be more acidic in composition than the normal gabbro. It is, therefore, more probable that it is merely a garnetiferous phase of the gabbro.

Structural Relations.

Internal. The most common internal structural feature exhibited by the rocks of the Buckingham series is the occurrence of the ferromagnesian and feldspathic constituents in aggregates so that the rocks present a heterogeneous appearance. This phenomenon is strikingly illustrated by the masses of pyroxenite included in gabbro observed in the northwestern part of the area mapped.

The other members of the series, gabbro, pyroxene syenite, and pyroxene diorite occur in separate outcrops, so that their relationship to one another was not observed, but it is probable that they belong in part at least to separate masses intruded into garnet gneiss belonging to the Grenville series.

In these cases, therefore, it is probable that the differentiation of the syenite and gabbro from the original magma occurred before the masses were intruded.

External. It was inferred in the discussion of the structural relationships of the Grenville series that the rocks of the Buckingham series had been intruded into the Grenville series, but that the direct evidence of intrusions had been largely obliterated by deformation. They occur most commonly as bands interlaminated with the rocks of the Grenville series and apparently conform in the main to the stratification in these rocks. It is probable, therefore, that they were intruded as sills.

Correlation.

After completing the examination of the St. Remi areas, the writer made a short reconnaissance between Montfort on the Huberdeau branch of the Canadian Northern railway, and Piedmont on the Mont Laurier branch of the Canadian Pacific railway, for the purpose of comparing the rocks of the Buckingham series with those mapped as anorthosite by Sir William Logan.[1]

It was found that the area indicated as anorthosite in this section, in reality consisted of zones of pyroxene diorite, pyroxene-quartz monzonite, and anorthosite interbanded with and intruded by granite gneiss. It would seem evident, therefore, that in places at least, the anorthosite of Logan included a large proportion of other pyroxenic rocks, and that the Buckingham series and the rock classed as anorthosite in this locality by the early geologists, have the same geological relationships and are probably equivalent in age.

METAMORPHIC PYROXENITE.

Throughout the Grenville belt, masses of rock consisting of diopside, scapolite, wollastonite, titanite, tourmaline, and other minerals of the lime silicate or pegmatitic class, to which the name pyroxenite has been generally applied, are commonly associated with the limestone member of the Grenville series. Since these masses, however, are believed to have been formed by the interaction of siliceous solutions with the limestone member of the Grenville series, the name metamorphic pyroxenite is used by the writer.

Rocks of this class were observed in the St. Remi area in association with the graphite deposits on lots 15, 16, and 17, range VI, Amherst township (Plate VII), and in a cut on the Canadian Northern railway at the point where the railway line intersects the northern edge of a granite ridge on lot 15, range VII, south, Amherst township.

The rock associated with the graphite deposits consists predominantly of wollastonite with pyroxene, scapolite, orthoclase, titanite, and graphite as less abundant constituents. In the occurrence on lot 15, range VII, south, on the other hand, the dominant mineral is a green diopside, with which scapolite is intergrown in places. The other minerals observed to be present were calcite, titanite, tourmaline, and pyrite.

In some localities within the Grenville belt, the relationships of the metamorphic pyroxenite are such as to indicate that the solutions by which the rock was formed emanated from the intrusives of the Buckingham series. In other localities, however, similar rocks are present which are evidently related to the later batholithic intrusions of granite and syenite. The wollastonite rock, in which the graphite on the property of Graphite, Limited, lots 15, 16, and 17, range VI, Amherst township, is found,

[1] Map in atlas accompanying the Geology of Canada, 1863, showing the distribution of Laurentian rocks in parts of the counties of Ottawa, Terrebonne, Argenteuil, and Two Mountains.

occurs as contact zones bordering masses of pyroxene granite which, probably, represent a phase of the pyroxenic gneisses, so that the metamorphism in this case is evidently related to the Buckingham series rather than to the later batholithic intrusives. The mass of pyroxenite exposed in the cut on the Canadian Northern railway, on the other hand, adjoins the younger porphyritic quartz syenite belonging to the batholithic group and passes transitionally into it by a gradual decrease in the proportions of pyroxene present, a relationship which might result from the interaction of the igneous rock with the limestone. It is possible, therefore, that this mass of pyroxenite may be related in origin to the later batholithic intrusives. It has, nevertheless, been placed in the legend of the accompanying map as older than these rocks, because in most localities in the eastern part of the Grenville belt the pyroxenite is known to occupy this stratigraphical position.

GRANITE-SYENITE GNEISS.

General Statement.

The granite-syenite gneiss member of the basal complex is widely represented throughout the Grenville subprovince in batholithic masses, bosses, and dykes intruding the rocks of the Grenville and Buckingham series which preceded them. In most districts the rocks of this class are represented by two phases—a coarse porphyritic type and a fine aplite-like variety; but in the St. Remi district, only the former was observed.

Distribution.

Within the area mapped, the batholithic intrusions occur in two principal areas, the eastern and northeastern part of the district and the southern part of range VI, Amherst township. A few detached masses also outcrop close to the southeastern border of the area. These, however, may possibly be connected with the larger masses beneath the overlying drift.

Lithological Character.

The granite-syenite member of the basal complex in the St. Remi district is generally a coarse porphyritic rock consisting of phenocrysts of orthoclase up to an inch or more in length, embedded in a matrix of feldspar or feldspar and quartz and small quantities of ferromagnesian minerals. A thin section prepared from a specimen of a porphyritic granite that outcrops in a cut on the Canadian Northern railway, on lot 12, range VII, south, Amherst township, was found under the microscope to consist of orthoclase, containing small perthitic inclusions, plagioclase, quartz biotite, amphibole, titanite, apatite, and iron oxide. The plagioclase present in the rock is easily distinguished from the associated quartz and orthoclase by its slightly decomposed condition. It has the optical properties of andesine. The quartz is very abundant in the rock, occurring in large, irregular grains in which numerous hair-like inclusions are disseminated. As far as was observed, these have no definite orientation with respect to the crystallographic directions of the quartz. The biotite is a pale yellow to red brown variety occurring either in association with the amphibole or in minute flakes disseminated through small areas of granular quartz and feldspar. The amphibole occurs in large, irregular grains up to 1 mm. in diameter. It is pale yellow to light green and is generally more or less decomposed.

Structural Relationships.

Internal. The porphyritic granite and syenite occurring in the St. Remi district is a comparatively massive type in which the foliation is scarcely discernible except in a few local areas, as for example, in the rock mass exposed on the Canadian Northern railway, on lot 13, range VII, south, where a typical augen structure has been developed. The trend of the foliation conforms in general to the local trend of the different parts of the batholithic mass. Thus in the region adjoining the western border of the quartzite belt in range VI, south, the trend of foliation is northwesterly, whereas in areas adjoining the valley of Pike creek in the northern part of the district it is northeasterly.

External. The study of the structural relationships of the batholiths of granite and syenite gneiss in other parts of the Grenville subprovince has shown that these masses are distributed in northeasterly trending zones and have made room for themselves partly by thrusting aside the older rocks and partly by lit par lit injection along the planes of bedding and foliation in the older rocks. In the St. Remi district it may be observed from an examination of the accompanying map that the foliation in the batholithic masses of granite and syenite parallels the structural trend of the adjoining rocks of the Grenville and Buckingham series and that the older rocks apparently dip under the batholiths along their eastern border as if the granite and syenite had been intruded in the form of huge sills. It is more probable, however, that these relationships are in reality the result of deformation; for the batholiths occurring in the St. Remi district are merely parts of a huge massif which it is believed was intruded into the rocks of the Grenville and Buckingham series as an accompaniment of a mountain building crustal movement, and under such conditions, the offshoot batholithic masses after their intrusion would be subjected to the same deformation as the intruded rocks and might thus be forced into a conformable attitude. In the St. Remi district the rocks of the basal complex apparently lie on the southeastern limb of a northeasterly trending anticline, the strike being generally northeasterly and the dip southeasterly, but the belt of Grenville quartzite in which the kaolin is found apparently became detached from the main mass of the Grenville series and assumed a north-northwesterly structural trend.

Correlation.

The batholithic granite and syenite occurring in the St. Remi district forms a part of the complex originally classed as Laurentian by Sir William Logan and probably belongs to the Laurentian as this term has been defined by the Geological Survey in eastern Ontario and southern Quebec, but in recent years an attempt has been made to classify all the Pre-Cambrian granitic rocks of the St. Lawrence basin as belonging to two and only two, periods of intrusion, Laurentian and Algoman, an assumption theoretically improbable, and proved by observations in the field to be untrue.[1] The use of the term Laurentian in this report might, therefore, imply a correlation with similar rocks in other parts of the Pre-Cambrian complexes of the St. Lawrence basin that is unwarranted.

LATE PRE-CAMBRIAN INTRUSIVES.

Diabase.

Along the southern border of the Laurentian highlands adjoining the lower Ottawa and lower St. Lawrence rivers a remarkably uniform system of diabase dykes extends continuously for nearly 200 miles. Although the individual dykes belonging to this system are generally not more than 200 or 300 feet wide, yet some of the dykes are known to continue without interruption for at least 100 miles. In the St. Remi district, as far as was observed, only one dyke of this class is represented. This intersects the south end of the gabbro ridge outcropping on lot 24, range A, Amherst township. It is approximately 40 feet in width, outcrops for 600 feet along the strike, and has the usual east-west trend and lithological character of the dykes of the system to which it belongs.

QUATERNARY.

Glacial

In common with the Laurentian highlands generally, the bedrock surface in this region is overlaid by an irregular mantle of glacial debris. This consists chiefly of boulder clay, sand, and gravel distributed partly in well-defined esker-like ridges, but mainly in thick, irregular masses. The most extensive area of this material occurs in the drift covered upland lying in the western part of range VI, Amherst township; the most striking of the esker-like ridges is that indicated on Map 1681 as extending diagonally across lots 1, 2, and 3, range V, south, Amherst township.

The direction of glacial movement in the St. Remi district, as indicated by the glacial striæ, was approximately from north to south. The presence of the kaolin deposits possibly affords a very definite estimate of the amount of material eroded from the surface of the Laurentian plateau by the continental ice-sheets in this locality, for it is possible that these deposits have been formed by the residual downward concentration of kaolin resulting from surface weathering, and if the deposits have orginated in this manner, then the erosive action of the continental glaciers was scarcely more than sufficient to remove the weathered debris from the bedrock surface. It is pointed out in Chapter IV, however, that it is also possible that the kaolin contained in the St. Remi deposits has been brought up from a deep-seated source by thermal waters ascending along the zone of faulting and fracture in which the kaolin occurs.

[1] Wilson, M. E., Geol. Surv., Can., Mem. 103, 1918, pp. 65–75, "The subprovincial limitations of Pre-Cambrian nomenclature in the St. Lawrence basin," Jour. Geol., vol. XXVI, 1918, pp. 325–333.

Marine Clay and Sand.

Throughout the lower part of the St. Lawrence basin generally, the glacial and older formations are overlain by stratified clay and sand which contains marine shells and which forms extensive flats in depressions within the Laurentian highlands up to points over 100 miles from its southern border. The maximum elevation at which these deposits are known to occur in the Ottawa valley is approximately 735 feet. Within the district described in this report, two flats of this class underlain by gravel, sand, silt, and clay occur, the upper of which, the St. Remi, has an elevation of 701 feet, and the lower, the Rockaway, an elevation of 663 feet above sea-level. Marine shells or other positive evidence of marine origin were not obtained within the deposits themselves, but they are classed as marine because they are uniformly stratified deposits lying in depressions opening towards the main St. Lawrence lowland depression to the southward in which the marine deposits occur and lying below the maximum elevation to which these deposits are known to occur.

CHAPTER IV.

MINERAL DEPOSITS.

GENERAL STATEMENT.

The principal mineral materials of commercial value so far discovered in the St. Remi district are kaolin, kaolinic quartzite, cornish stone, graphite, phlogopite (amber mica), and dolomite. Of these, only the kaolin, kaolinic quartzite, cornish stone, and graphite are known to occur within the area included in the accompanying map.

KAOLIN, KAOLINIC QUARTZITE, AND CORNISH STONE.

HISTORY OF DEVELOPMENT.

In the summer of 1894, Milion Thomas, while digging a well on the farm of Philibert Tasse, encountered kaolin at a depth of 15 feet and sent a small quantity of the material to Richard Lanigan of Calumet, who identified the sample as kaolin and purchased the right to mine the material from the owner of the property. No attempt was made to determine the extent of the deposits at that time, however, and it was not until 1911 that actual development work on the deposits was commenced.

In the autumn of 1909, Mr. F. R. Lanigan, of Montreal, acquired from the government the mining rights to parts of lots 4, 5, 6, 7, and 8, range VI, south, Amherst township, and in 1911, having leased these rights to Mr. J. C. Broderick of Montreal, formed the St. Remi Kaolin Company, to take over the ownership of the property. In 1911, some development work was performed and the construction of a washing plant begun by Mr. Broderick, and in 1912 the Canadian China Clay Company was organized to continue mining operations under the terms of Mr. Broderick's lease. In 1913 the Canadian China Clay Company purchased the mining rights to parts of lots 4 to 8, range VI, south, Amherst township, from the St. Remi Kaolin Company; the mining rights to parts of lots 2 and 3 and additional parts of lots 2 to 8, range VI, south, Amherst township, from the government; and the surface rights to all these lots, from the local owners. Since that time the washing plant on the property has been enlarged, some trenching, stripping, and drilling for the purpose of developing the deposits completed, and several thousand tons of kaolin produced. Prior to 1916 the washed product had to be transported by wagon to Huberdeau, the terminus of the Huberdeau branch of the Canadian Northern railway, but in that year the railway was extended to the china clay deposits so that the cost of transportation from the mine has been greatly reduced.

The only known deposit of kaolin in the district, outside the area owned by the Canadian China Clay Company, occurs near Pike creek, on lot 8, range 4, Amherst township, and is owned by Mr. A. Lanigan of Calumet. This deposit, which had been known to Mr. Lanigan for a number of years, was staked by him in December, 1911.

DISTRIBUTION.

Deposits of kaolin have been discovered in the St. Remi district in two localities up to the present time, the principal occurrences in a zone approximately 1,000 feet in width extending in a north-northwest direction from lot 8 to lot 2, range VI, south, Amherst township, and a single deposit occurring near Pike creek on lot 8, range IV, Amherst township. The latter deposit occupies a position almost directly on the continuation of the principal zone of deposits farther to the south and may be another outcrop on the same zone, but whether or not a connexion exists has not been determined since there are no rock exposures in the intervening distance.

GENERAL CHARACTER.

Lots 2 to 8, Range VI, South, Amherst Township. In the western part of range VI, south, Amherst township, there is a north-south trending drift-covered ridge about one-half mile in width, which intervenes between rocky ridges of granite-syenite gneiss, and from which it is separated by well marked depressions. An examination of the bedrock surface exposed in outcrops and in the bottom of trenches, railway cuttings, and other excavations, shows that this ridge throughout nearly its whole extent is composed of vertical or nearly vertical beds of Grenville quartzite and garnet gneiss, which trend in a north-northwest direction, and that, whereas on the eastern slope of the ridge the quartzite is exceedingly massive and unbroken, on the western slope, throughout a zone approximately 1,000 feet in width, it has been shattered almost everywhere to a friable condition. Within this shattered zone kaolin occurs, finely disseminated between the quartz grains, in veins following the planes of fracture and movement and in more extensive deposits up to 100 feet in width and several hundred feet in length. Owing to the presence of the thick overburden of glacial drift which nearly everywhere covers the ridge, the whole extent of the shattered zone in which the kaolin is found has not yet been determined, but sufficient information has been obtained by means of trenches, test pits, and stripping, to indicate that the zone extends in a direction north 20 degrees west, parallel to the structural trend of the quartzite, and is continuous for approximately 7,000 feet.

The most extensive deposits of kaolin so far discovered in this shattered zone are lots 5 and 6, where an almost continuous lead of kaolin, ranging from a few feet to 100 feet in width, has been laid bare by stripping and test pits for a distance of 1,400 feet. Bore-holes on this deposit show that it persists to a considerable depth beneath the surface, a depth of 150 feet in kaolin having been attained at one point. Although the kaolin leads everywhere contain considerable quartzite either in the form of fragments or finely disseminated grains, the determination of the amount of kaolin contained in average samples shows that the kaolin content in the masses of kaolin as a whole is not less than 35 per cent.

Throughout other parts of the shattered zone numerous kaolin leads ranging from a fraction of an inch up to 65 feet in width have been discovered at several points where the drift cover has been removed from the bedrock surface. The deposits of this character so far discovered on the various lots are the following:

Lot 2	Leads 65 and 12 feet wide in trenches.
Lot 5, east of main deposit	Leads 5, 21, and 1 foot wide in test pits.
west of main deposit.	Numerous leads from ½ inch to 4 feet in width.
Lot 6	Lead in excavation for spring.
Lot 7.	Lead of kaolin ½ inch in width in broken kaolinic quartzite exposed in cutting on Canadian Northern railway.
Lot 8.	Half inch leads of kaolin, in broken kaolinic quartzite exposed in cutting on Canadian Northern railway.

At the time the kaolin deposits were examined by the writer in September, 1916, a trench for a pipe-line had been excavated from the main pit to the washing plant of the Canadian China Clay Company, the bottom of which intersected fractured, kaolinic quartzite for a distance of 133 feet from the wall of the main pit southward. Continuous average samples were taken at intervals of 10 feet along the bottom of the trench and the percentage of kaolin in each sample determined by the loss in weight on removing the kaolin from the crushed material by decantation. The description of the samples and the percentage of kaolin contained in each was as follows:

Feet.	Description of sample	Per cent of kaolin
1 to 10	6 leads ¼ to ½ inch wide.	14½
10 to 20	4, ½-inch leads.	10
20 to 30	3, ½-inch; 1, 2-inch; 1, 4-inch; and 1, 6-inch lead.	16
30 to 40	1, 6-inch and 1, 2-inch lead.	11
40 to 50	1, 6-inch lead.	7¾
50 to 60	1, 2-inch and 1, 8-inch lead.	15¾
60 to 70	1, 4-inch lead.	11
70 to 80	2, ½-inch and 1, 7-inch lead.	13
80 to 90	1, 2-inch lead and 3½ feet of exceedingly friable kaolinic quartzite.	15
90 to 100	1, ½-inch and 1, 3-foot lead.	17
100 to 110	No leads.	2
110 to 120	Exceedingly friable but no leads.	10
120 to 130	1, 2-inch lead.	6
130 to 133	No leads.	2¼

Average kaolin content for whole section equals 11¼ per cent.

Lot 8, Range IV, Amherst Township. At the east end of lot 8, range IV, Amherst township, kaolin is exposed in the bottom of a few small pits excavated on the bank of Pike creek. The material composing these deposits consists of grains of quartz, aggregates of kaolin, and rusty zones containing disseminated flakes of muscovite. The distribution of these constituents is remarkably similar to that of the constituents composing the granite-gneiss of the region, the quartz grains occurring disseminated in a manner similar to quartz grains of the granite, the kaolin similar to the feldspar, and the rusty zones similar to the ferromagnesian constituents. It seems probable, therefore, that this deposit has been formed by the alteration of granite-gneiss.

STRUCTURAL FEATURES.

The outstanding structural feature of the kaolin deposits is their very evident association with a zone of deformation throughout which the Grenville quartzite has been faulted, fractured, and minutely shattered to a friable condition.

Faulting.

Owing to the poorly exposed condition of the zone of deformation it has not yet been positively determined whether it is associated with a single fault of considerable displacement or with a series of small faults. It is significant, however, that the only localities where positive evidence of faulting can be observed are all associated with the principal deposit of kaolin on lots 5 and 6, range VI, south, Amherst township.

The locality at which the evidence of faulting in association with the principal kaolin deposit was most apparent at the time the deposit was examined by the writer was on the south face of No. 2 pit of the Canadian China Clay Company on lot 6 (Figure 2). At this point the quartzite beds adjoining the foot-wall of the fault have been dragged downward from a vertical to a recumbent or overturned attitude, a feature which indicates that the movement along the fault plane was considerable. Indications of faulting can also be seen on the west face of No. 1 pit on lot 6 (Plate VB). Here the surface of the quartzite beds exhibits the gently curving and vertically ridged appearance commonly present on rock faces along which displacement has occurred. The fault plane with which the principal kaolin deposit is associated parallels the structural trend of the quartzite in which it occurs, and trends in a direction 20 degrees west of north.

Jointing.

The second structural feature indicating that the kaolin deposits are associated with a zone of deformation in the Grenville quartzite is the jointed character of the quartzite wherever the kaolin is found. It is possible that when the drift cover is removed from the zone of deformation it will be found that the planes of jointing fall into definite systems, but, in the present unexposed condition of the deposits, the data upon which such generalizations could be based are not yet available. At some points two well developed intersecting systems of joints were observed to strike almost at right angles to the strike of the quartzite beds (north 70 degrees east), and to dip approximately at 45 degrees; at other points the quartzite shows a tendency to break horizontally (Plate VA); but in ost localities the conspicuous joint planes occur in systems which intersect the quartzite beds obliquely on the strike and vertically on the dip, with the result that the quartzite tends to break into columnar blocks.

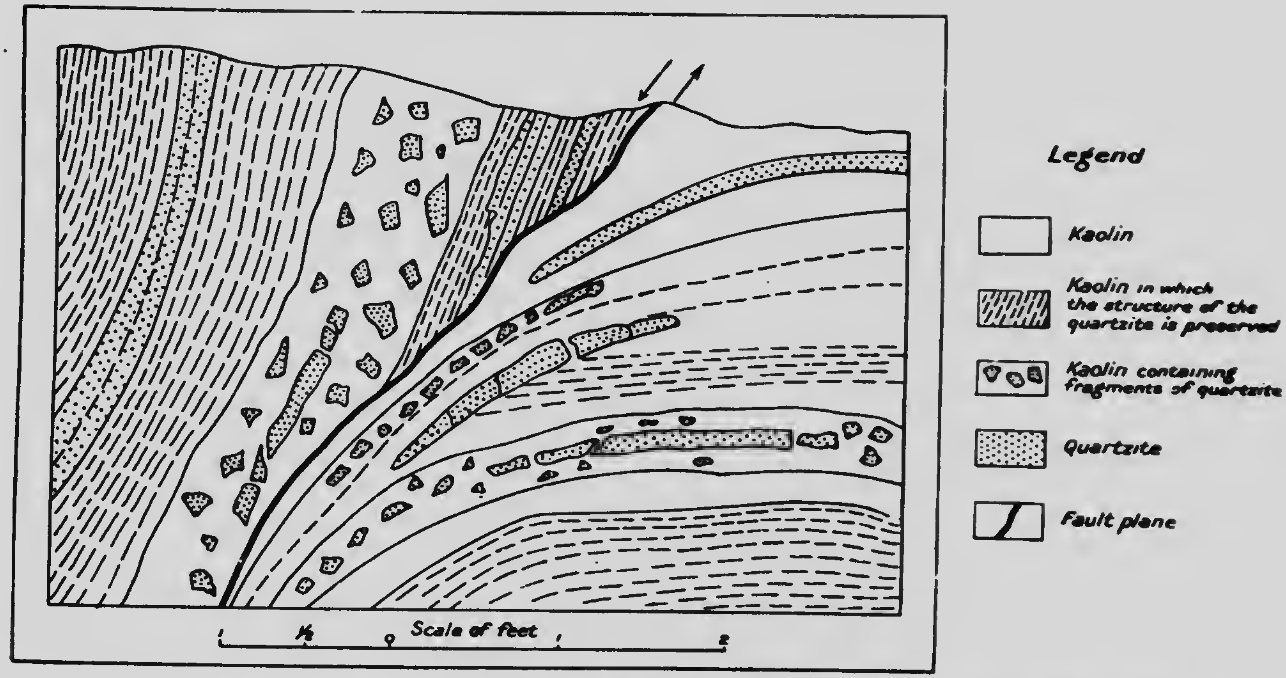

Figure 2. Section of south face in pit in china clay deposit on lot 6, range VI, south, Amherst township, Quebec.

Granular Fracturing.

The third deformational effect exhibited by the zone in which kaolin occurs is the remarkable manner in which granular fracturing has occurred in the quartzite. Throughout nearly the whole of the fracture zone the quartzite has been broken to a more or less friable condition and in places has been crushed to dust.

REPLACEMENT.

The evident association of the kaolin deposits of the St. Remi district with a zone of faulting and fracture and the occurrence of masses of kaolin in the deposits, forming a matrix enclosing broken masses of quartzite, would seem to indicate that the kaolin deposits had been formed entirely by the deposition of kaolin in openings resulting from the deformation of the Grenville quartzite; but there is also much evidence to indicate that large masses of kaolin have been deposited by replacement, that is the quartzite adjoining the planes of faulting and fracture has been carried away in solution by circulating waters and kaolin deposited in its place. The principal observations on which this conclusion is based are: (1) that the surfaces of the quartzite beds adjoining the planes of bedding are channeled and pitted with caverns (Plate VIA) in which the kaolin has been deposited; (2) that beds of quartzite remain in their original vertical attitude here and there within the kaolin deposits (Figure 2); (3) that the bedded structure of the quartzite is preserved in the kaolin deposits in places; (4) that the quartz grains contained in the quartzite have a marked vertical elongation and this elongation is preserved by the quartz grains contained in the kaolin even where the kaolin constitutes 75 per cent of the deposit. The photographs of specimens shown in Plates I and VI B have been inserted to illustrate this feature. In Plate I a specimen of quartzite exhibiting the vertically linear structure of the quartz grains is shown; in Plate VI B the residual quartz contained in the kaolin retains the same linear arrangement.[1]

COMPOSITION.

In the northern part of the fracture zone, the kaolin deposits consist almost entirely of white to cream white kaolin and quartz, other constituents being either uncommon or only local in their occurrence; in the southern part of the zone, on the other hand, the greater part of the outcrop so far disclosed by stripping operations is coloured in various shades of red, brown, and yellow from the presence of disseminated hydrous iron oxide, but whether this is merely a superficial discoloration or persists in the deposits at depth has not yet been determined. The uncommon impurities observed in the kaolin deposits are fine flakes of muscovite, aggregates of tourmaline, and disseminated flakes and aggregates of graphite.

That the normal white to cream white kaolin contained in the St. Remi deposits is remarkably free from impurities is indicated by the

[1] Hayes, C. A., Bull. Geol. Soc. Am., vol. VIII, 1897, pp. 213-220.

analyses of the washed product, included in columns I and II of the following table.

Analyses of Kaolin from Amherst Township, Compared with Analyses of Kaolin from Other Countries.

	I	II	III	IV	V
Silica	46·13	44·43	46·17	47·10	45·78
Alumina	39·45	40·48	38·42	39·42	36·46
Ferric iron }	0·72	0·039	0·43	0·23	0·28
Ferrous iron }		0·24	0·09	0·31	0·50
Lime	none	0·36	0·04	0·24	0·04
Magnesia	none		}	0·16	}
Potash	0·20		2·77	0·08	0·25
Soda	0·09		}	0·13	}
TiO_2					
Loss on ignition	13·81	14·46	12·01	12·24	13·40
Moisture					2·05
Total	100·40	100·01	99·93	99·91	98·84

I. St. Remi, Amherst township, Labelle county, Quebec. Analysis by G. F. Lundell.
II. St. Remi, Amherst township, Labelle county, Quebec. Analysis by Milton Hersey Company, Can. Min. Jour., vol. 33, 1912, p. 441.
III. Jackson, W. and Richardson, A. G., Trans. Eng. Ceramic Soc., vol. 3, 1903, p. 56.
IV. Mellor, J. W. and Holdcroft, A.D., Trans. Eng. Ceramic Soc., vol. 10, 1911, p. 94.
V. North Carolina, Geol. Surv., Bull. 13, 1897.

The analyses of typical kaolin from localties in England and United States have been inserted in columns III to V for the purpose of comparison.

The chemical composition of the discoloured kaolin, according to an analysis by A. G. Spencer, is as follows:

	Per cent.
Silica	54·24
Alumina	34·24
Iron oxide	2·04
Lime	2·54
Magnesia	0·46
Loss on ignition	5·87

In a small pit near the east border of the fracture zone on lot 5, range VI, south, Amherst township, an altered, feldspathic rock having approximately the composition of cornish stone, has been found. A chemical analysis of this material was made by Mr. A. G. Spencer, of the Canadian Testing Laboratories, Montreal, with the following result:

	Per cent.
Silica	72·96
Alumina	17·30
Potash	6·41
Lime	1·50
Magnesia	0·65
Iron	0·10
Water	1·10

A specimen of this rock, sent the writer by Mr. Broderick, of the Canadian China Clay Company, could be seen with the naked eye to consist of numerous grains of quartz and scattered flakes of muscovite embedded in feldspar. An examination of a thin section of the rock under the microscope showed that the feldspathic constituent present was a plagioclase having the optical properties of andesine ($Ab_{65}An_{35}$), in which a kaolinized feldspar, presumably orthoclase, was perthitically included. That the rock had been subjected to considerable deformation was indicated by the undulatory extinction of the quartz and the broken and bent condition of the feldspar. Both the quartz and the feldspar contained numerous hair-like inclusions of a mineral having a high refringence and birefringence and parallel extinction—possibly rutile. These had apparently no definite orientation with respect to the crystallographic direction of the mineral enclosing them.

At the time the writer visited the district last (July, 1918), a shaft was being sunk on the property of the Canadian China Clay Company, at a point approximately 75 feet to the east of the washing plant, and hence on the western border of the fracture zone in which the kaolin occurs. The rock encountered in this shaft is a heterogeneous, coarse, garnet gneiss in various stages of kaolinization. In its least altered phases it consists of orthoclase in the incipient stages of kaolinization, a few grains of quartz, broken aggregates of red garnet, fibrous sillimanite, red brown mica, scattered flakes of muscovite, and small grains of a dark brown, highly refractive, mineral, probably rutile; in its more highly altered phases it retains its original texture, but is stained yellow with iron oxide and has been kaolinized to a friable condition.

ORIGIN.

It has been pointed out, in the sections of the report in which the structural features of the kaolin deposits and the evidences of replacement which they exhibit were discussed, that the kaolin leads occur in association with a wide zone of faulting and fracture traversing Grenville quartzite and have been formed partly by the deposition of kaolin along the planes of fracture and faulting and partly by replacement of the friable quartzite wall rock. The association of the kaolin deposits with a zone of fracture and faulting is of considerable economic importance, since the horizontal extent of the deposits is directly related to the extent of the zone or zones of deformation. It is equally important, however, from a commercial standpoint, that the source from which the kaolin was derived be determined; for, if the kaolin has been carried down into the zone of deformation from a superficial source, the deposits may disappear before the depth to which mining operations might be carried on is reached; on the other hand, if the kaolin has been derived from a deep-seated source, it is reasonably certain that the deposits persist to depths beneath the limit to which the kaolin could be profitably mined.

The discussion which follows of the origin of the kaolin deposits has been divided into three parts: (1) a summary statement of the various ways in which kaolin deposits found in other parts of the world are believed to have originated; (2) a discussion of the evidence indicating the manner in which the St. Remi deposits have originated, and (3) a concluding section in which the conclusions with regard to the origin of the St. Remi deposits are inferred from the evidence cited in sections 1 and 2.

Summary Statement of Hypotheses.

The hypotheses which have been suggested to explain the origin of kaolin, although varied and numerous, all fall into one or other of two classes, according to whether the source of the kaolinizing agency has been superficial or deep seated.

Kaolin of Superficial Origin.[1] There are two groups of hypotheses belonging to this class: in one the importance of certain minerals from which the kaolin is believed to have been derived is emphasized, and in the other the particular agency by which the kaolinization is effected is regarded as important.

The oldest and most generally accepted hypothesis to account for the origin of kaolin has been that it is formed as a product of the processes of mechanical disintegration and chemical decomposition to which rocks exposed at the earth's surface are subjected in weathering. The formation of kaolin in this manner has been called in question by some geologists in recent years; nevertheless, it is still believed by others to be the only reasonable explanation of the origin of many deposits. Occurrences of kaolin that have been described in recent years as having originated by kaolinization in the zone of weathering are found in the island of Bornholm[2], at Josingsfjord, Ekersund-Soggendal, Norway[3], at Meissen and Halle in Saxony[4], and in numerous localities in United States[5].

It has been generally assumed that the principal source from which kaolin is derived in weathering is the feldspars, the chemical reaction by which this change is effected in the case of orthoclase being as follows:

$$K_2O, Al_2O_3, 6SiO_2+2H_2O+CO_2=Al_2O_3, 2SiO_2, 2H_2O+K_2CO_3+4SiO_2.$$

The formation of kaolin by the weathering of muscovite, an hypothesis originally suggested by Schmid[6], has been advocated in recent years by Selle[7] for the kaolin deposits at Halle in Saxony, and by Hickling for the Cornwall kaolin deposits. Since both Selle and Hickling regard the muscovite as merely an intermediate stage in the transformation of feldspar into kaolin, this is merely a modification of the prevailing theory of kaolinization of feldspar. The kaolinization of scapolite by weathering has also been advocated by Fuchs and by Gummel[8] to account for the formation of deposits of kaolin occurring in the vicinity of Passau in Bavaria. With

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[1] Exogene kaolin, Stahl Alfred, Die Verbreitung der Kaolinlagerstatten in Deutschland, Archiv. fur Lagerstatten-Forschung in Deutschlands, Heft 12, 1912, p. 109.

[2] Winkel, H. E., Kaolinslemmeriet, Rabekkegaard paa Bornholm, Denmark, 2 Tav. Kjobenhavn, Tekn. Forenings Tidsskrift, 1885.

[3] Vogt, J. H. L., "The genesis of ore-deposits," 2nd ed., 1902, pp. 661-665.

[4] Barnitzke, J. E., Uber das Vorkommen der Porzellanerde bei Meissen und Halle a.S., Zeitschr. fur prakt. geol., 1909, pp. 457-473.
Wust, E., Die Entstehung der Kaolinerden der Gegend von Halle a.S., Zeitschr. fur prakt. geol., 1907, pp 19-23.

[5] Ries, H., Md. Geol. Surv., vol. 6, 1904.
North Carolina Geol. Surv., Bull. 13, 1897.
U. S. Geol. Surv., Prof. Paper No. 11, 1903.
"Clays, their occurrence, properties, and uses, 1908"
Trans. Am. Ceramic Soc., vol. 13, 1911, pp. 52-74.
Ries, H., Kummel, H. B., and Knapp, G. N., Geol. Surv. of New Jersey, vol. 6, 1904.
Watts, A. S., U.S. Bur. Mines, Bull. 92, 1915.

[6] Schmid, E. E., Die Kaoline des thuringischen Bundsandsteins, Zeitschr. deutsch geol. Gas, vol. 28, 1876, p. 110.

[7] Selle, V., Uber Verwitterung und Kaolinbildung Hallescher, Quarzporphyre, Zeitschr. fur. Naturw. Halle, vol. 79, 1907.
Hickling, G., Trans. Inst. Min. Eng., vol. 35, 1908-09, p. 10.

[8] See H. Risler, neues Jahrback fur Min. Geol. und Pal., vol. 15, 1902, pp. 256-258.

these few exceptions, however, geologists are generally agreed that in so far as kaolin has been formed by weathering, it has been derived in the main from feldspar.

The agencies which are believed by various writers to have been especially effective in bringing about superficial kaolinization include carbon dioxide, waters derived from swamps, hydrolysis, and sulphuric acid formed by the oxidation of sulphides. That carbon dioxide contained in percolating waters has been a most potent agency in bringing about the decomposition of silicates was long ago proved experimentally by Bishof, Mueller, Daubree[1] and others,[2] and the probable importance of the role it plays in kaolinization has been generally recognized. The common occurrence of many kaolin deposits in Germany, associated with feldspathic igneous rocks at points where they underlie coal beds, has led many German geologists to conclude that the kaolinization in the case of these deposits has been brought about by percolating swamp waters. It has been pointed out by Cameron and Bell[3] that many minerals are soluble in water alone and that kaolinization might, therefore, occur without the presence of carbon dioxide or other dissolved material. The kaolinization is assumed to take place by hydrolysis, the reaction in the case of orthoclase being as follows:

$$KAlSi_3O_8 + HOH = HAlSi_3O_8 + KOH$$

$$HAlSiO_3O_8 - 2SiO_2 = HAlSiO_4$$

Kaolin is also believed to have been formed in some cases, at least, through kaolinization by sulphate solutions formed by the oxidation of the sulphides contained in ore deposits.[4] One of the most evident examples of kaolinization by sulphate solutions formed in the oxidized zone occurs at the Helen iron mine at Michipicoten, Ontario. In this locality a diabase dyke has been kaolinized at the point where it intersects the ore mass which consists of hematite and goethite and which is believed to have been formed by the oxidation of pyritic siderite with which the iron ore is associated. The diabase dyke, although wholly unaltered where it intersects the adjoining iron formation, has been completely kaolinized where it crosses the ore-body, and is said by Parsons to be less unaltered in the lower workings where the alteration of the siderite and pyrite is less complete.[5]

Kaolin or Kaolinizing Agency of Deep-seated Origin. The hypotheses of this class usually have reference to deposits which have been formed *in situ* by the alteration of pegmatite, granite, and related rocks, and it is the agency by which the kaolinization has been effected rather than the kaolin that is regarded as deep seated in its origin. In the St. Remi deposits, however, the kaolin has not been developed *in situ*, and if it is of deep seated origin it must have been carried up from below.

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[1] Bishof, G. C., Lehrbuch der chem. und physikalischen Geologie, Bonn. 1855.
Mueller, R., Tscherm. Min. Mittheil, vol. 7, 1877, pp. 30–48.
Daubree, A., Etudes synthetiques de geologie experimentale, 1879, pp. 268–273.

[2] Merrill, G. P., "Rocks, rock weathering, and soil," Macmillan Company, New York, 1897; Van Hise, C.R., U. S. Geol. Surv., Mon. 47, 1904, pp. 473, 483; and Clarke, F. W., U. S. Geol. Surv., Bull. 491, 1911, p. 349.

[3] Cameron, F. K., and Bell, B., U. S. Dept. Agr., Bur. of Soils, Bull. 30, 1905.

[4] Lindgren, W., Econ. Geol., vol. 2, 1907, p. 120.
Ransome, F. L., Econ. Geol., vol. 2, 1907, p. 689; U. S. Geol. Surv., Prof. Paper 66, 1909.
Jacquet, J. B., Geology of the Broken Hill lode and Barren Ranges mineral field, New South Wales, 1894, p. 89.

[5] Parsons, A. L., Ont. Bureau of Mines, Ann. Rept., vol. 24, pt. 1, 1915, pp. 185–215.
Bolton, L. L., personal communication.

The kaolinization of granite and other igneous rocks at Carlsbad and other localities through the agency of cold springs charged with carbon dioxide has been noted by Stremme[1, 2], Gagel,[1] and Grupe,[2] but with these exceptions the hypotheses of this class all assume that the kaolinization has been effected by ascending thermal waters or gasses. The origin of kaolin by pneumatolytic processes was suggested as early as 1824 by von Buch, who noted the presence of fluorspar in the kaolin deposits of Halle, in Saxony, and concluded that the kaolinization had been brought about by hydrofluoric acid vapours. Since von Buch made his original suggestion the pneumatolytic theory has been advocated by numerous writers, including Collins,[4] and Butler[6] for the Cornwall kaolin deposits; Daubree, DeLauny[5], and Mallard for certain occurrences of kaolin in France; Forshhammer and Eichstadt for Scandinavian deposits, and Rosler[6] and Stutzer[7] for German kaolin deposits.

The principal data upon which those who favour the pneumatolytic theory base their conclusions are the following: (1) the common association of kaolin with tourmaline, fluorspar, topaz, pyrite, and other minerals of pneumatolytic origin; (2) that kaolin deposits are commonly associated with faults and fissures which afford channels along which the kaolinizing vapours could ascend; (3) that the normal weathering of granite does not result in a pure white kaolin; (4) that the first stage in the weathering of a granite is mechanical disintegration, whereas in kaolin deposits original textures are commonly preserved (Plates I and VI B); (5) kaolin deposits extend to greater depths than could possibly result from surface weathering; (6) sericite is abundant in kaolins though this mineral is not a product of weathering.

It is contended by Rosler that kaolin deposits are not only formed by ascending agencies, but that the kaolinizing agency is aqua-gaseous. Lindgren, on the other hand, as a result of observations in ore vein deposits, concluded that kaolin is not found in the deep vein zone, and, therefore, cannot be of pneumatolytic origin.

The evidence bearing on the various ways in which kaolin may have originated has recently been discussed at considerable length by Stahl, Ries, and Howe. Stahl concludes, from a study of the German kaolin deposits, that the formation of kaolin is easily effected by weak acids and in the case of German kaolin deposits only through the agency of carbon dioxide in aqueous solution, and that the kaolinizing agency penetrates the rock, in some cases from above (exogenous kaolins), partly as percolating atmospheric water, more commonly as swamp water, and less commonly as surface waters derived from graphite deposits, and in other cases from below (endogenous kaolins) in the form of cold acid waters or more rarely as thermal waters.[8] Ries, who is especially familiar with American kaolin deposits, likewise concludes that " a careful sifting of the evidence would seem to indicate that kaolin might be formed according to any one of the three important processes, viz., weathering, volcanic waters, and vapours

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[1] Gagel, C., and Stremme, V., Centralblat. fur. Min. usw., 1909.
[2] Stremme, V., and Grupe, O., Monatsber, der Deutsch, geol. gesel., 1910.
[3] Collins, J. H., Min. Mag., vol. 7, 1886–7, pp. 205–214.
[4] Butler, F. H., Min. Mag., vol. 15, 1908.
[5] DeLauny, L., Bull. Soc. Geol., France, 1888, vol. 16.
[6] See Rosler, H., Neues Jahrbuch fur Min. Geol. und Pal., vol. 15, 1902, p. 390.
[7] Stutzer, O., Zutschr. fur prakt, geol., vol. 13, 1905, pp. 333–337.
[8] Stahl, A., Die verbreitung der Kaolilagerstatten in Deutschland, Archiv. fur Lagerstatten-Forschung Heft 12, 1912.

or acidulated waters from coal beds and swamps. . . . . . .That kaolin may be formed by post-volcanic vapours or water is no doubt true, as shown by the formation of this mineral below ground water level in the wall rock of many veins, and the turquoise deposits of New Mexico,[1] but whether any commercially valuable deposits have thus originated remains to be proved[2]." Howe, on the other hand, in common with most geologists who have studied the Cornwall kaolin deposits, attaches somewhat greater importance to pneumatolysis. He concludes as follows: "It may be permissible, therefore, to regard carbon dioxide as most probably the principal accessory agent in kaolinization in all its varied modes of occurrence, though in no single case has the sequence of steps in the process been absolutely proved. It is clear there are many occurrences of kaolin which cannot be referred to pneumatolysis while there are others in which some form of igneous activity is the most obvious prime cause of kaolinization. In short, as F. W. Clarke has said, kaolin, like many other substances, may be formed by any of the several processes in all of which water, hot or cold, and carbonic acid take part. No one interpretation can fit all its occurrences."[3]

The conclusions of Stahl, Ries, and Howe indicate the present status of our knowledge with regard to the origin of kaolin. The German geologists, on the whole, with the exception of Rosler, regard surface alteration, and especially alteration effected through the agency of swamp waters, as the most important. Similarly, the geologists of United States, for the most part, regard kaolinization by weathering as the principal source of kaolin; the English geologists, on the other hand, who are familiar with the kaolin deposits of Cornwall attach greater importance to the pneumatolytic theory. All are agreed, however, that kaolin may be formed in many ways and the various conclusions of the different writers have reference mainly to the relative importance of the processes advocated.

St. Remi Deposits.

The kaolin deposits of St. Remi district are peculiar in that the most extensive leads do not occur in association with highly feldspathic rocks but with quartzite, so that the kaolin in these occurrences has been transported along the planes of fracture and faulting from an extraneous source either above or below the present location of the deposits.

Kaolin From a Superficial Source. There are two possible superficial sources from which the kaolin may have been derived. These are the quartzite-garnet gneiss belt in which the kaolin deposits are found, and the batholithic masses of granite and syenite gneiss which adjoin the quartzite-garnet gneiss belt.

The Grenville quartzite with which the kaolin deposits are associated generally contains sparsely disseminated feldspar, is intruded in places by dykes of granite or syenite, and includes beds of garnet gneiss; and since granite, syenite, and garnet gneiss all contain an abundance of orthoclase, it is possible that the kaolin deposits have been formed from feldspar by

[1] Zalinski, E. R., "Turquoise in Mexico," Econ. Geol., vol. 2, 1907, p. 464.
[2] Ries, H., Trans. Am. Ceramic Soc., vol. 13, 1911.
[3] Howe, J. Allen, "A handbook to the collection of kaolin, china-clay, and china-stone in the museum of practical geology," London, 1914.

downward concentration along the planes of faulting and fracture as the upper parts of the zone of deformation weathered away. As far as known at present, however, the proportion of feldspar contained in the quartzite and garnet gneiss, including all its modes of occurrence, is small, and, unless the proportion contained in the unexposed portions of the belt is larger than the exposed portion, the concentration of the kaolin deposits would require the weathering away of an enormous thickness of rock. Thus, if the quartzite-garnet gneiss belt contains an average of 5 per cent of orthoclase, and the zone of fracture and faulting, in which the kaolin occurs, contains an average of 20 per cent of kaolin to a depth of only 100 feet, the concentration of this kaolin by downward enrichment would involve the weathering away of nearly 800 feet of rock and 8 tons of silica and other impurities would have to be carried away in solution for every ton of kaolin produced.

It is probable that prior to the glacial epoch the surface of the batholithic granitic rocks of the Amherst area, like the unglaciated regions of North America at the present time, was covered with a thick mantle of weathered material, and that, as at the present time, the areas underlain by these rocks stood at a higher elevation than the belt of quartzite in which the kaolin is found. It is possible, therefore, that the kaolin in the St. Remi deposits may have been derived from the weathering product overlying the feldspathic rocks of the district, but this would involve the horizontal transportation of the kaolin for at least several hundred feet and it is doubtful whether the kaolin contained in the St. Remi deposits would have remained so remarkably pure if it had been transported this distance.

Kaolin From a Deep-seated Source. Since the quartzite garnet gneiss belt, in which the St. Remi kaolin deposits are found, lies between batholithic masses of granite and syenite gneiss, and these are merely parts of a huge massif extensively developed in this part of the Laurentian highlands, it is probable that the zone of fracture and faulting along which the kaolin is found intersects granite or syenite at depth. It is possible, therefore, that thermal solutions ascending along the fault plane might kaolinize the feldspar of the granite or syenite and then transport the resulting alteration product upward, redepositing it in the quartzite above. The principal evidence observed in the study of the kaolin deposits, that might have a bearing on this hypothesis, was the presence of sericite and aggregates of black tourmaline in the kaolin and in the quartzite wall rock. Where tourmaline crystals occur in the quartzite, it was observed that these generally seemed to lie on the surface of bedding planes or other openings where circulating waters had penetrated, and in no case extended very far into the solid rock (*See* upper part of Plate VI A). It seems apparent, therefore, that the tourmaline was deposited after the quartzite was fractured and faulted, and that highly heated aqueous or gaseous solutions at some time circulated through the fracture zone.

Conclusion. From the preceding discussion it is concluded that, as far as the writer was able to observe, evidence from which a definite conclusion with regard to the origin of the St. Remi kaolin deposits may be inferred, is not yet available. Nevertheless, there are certain features exhibited by the deposits that have definite bearing on the problem. These are: that the kaolin occurs in a zone of fracture and faulting traversing

Grenville quartzite and garnet gneiss; that the principal kaolin leads so far discovered occur in quartzite and hence the kaolin has not been developed *in situ* but has been transported into its present position; and that the relationships of the kaolin in places show that it has been deposited in part by the replacement of the quartzite wall rock. Whether the kaolin originated by superficial weathering and was carried down into the fracture zone, or was brought up from below by thermal waters, the writer is unable to decide. The presence of crystals of tourmaline, a mineral formed at high temperatures, indicating that thermal waters at some time circulated through the fault zone, might seem very positive evidence in favour of the deep-seated origin of the kaolin; on the other hand, the occurrence of oxidized and kaolinized garnet gneiss at a depth of 85 feet in the shaft recently sunk on the property of the Canadian China Clay Company is possibly equally positive evidence favouring the derivation of the deposits from a superficial source.

DISCOLORATION IN KAOLIN.

It has been previously noted (page 23) that a considerable part of the surface outcrops of the kaolin deposits on lots 5 and 6, range VI, south, Amherst township, are discoloured with iron oxide, so that the kaolin at such points is valueless for most of the purposes for which kaolin is used. The depth to which this discoloration descends is, therefore, of importance in estimating the extent and value of the kaolin deposits.

The process by which the discoloration of the kaolin is brought about is presumably either the infiltration of hydrous iron oxide derived from the overlying glacial drift or the oxidation in situ of the pyrite and other ferruginous impurities contained in the quartzite or garnet gneiss. The depth to which the discoloration descends in the deposits is limited by the depth of the ground water level, but, as far as known to the writer, no data is available from which the maximum depth of this point throughout the fracture zone might be inferred. The occurrence of oxidized material in the new shaft on the property of the Canadian China Clay Company indicates, however, that oxidation may descend, in parts of the zone at least, to a considerable depth.

EXTENT OF DEPOSITS.

General Statement.

As is indicated on the accompanying map, No. 1681, the belt of quartzite and garnet gneiss, with which the kaolin is associated, is almost entirely hidden beneath glacial drift and, along the continuation of the fracture zone in which the kaolin occurs, there are outcrops of rock beyond the known occurrences of kaolin for over 1,000 feet on the south and 5,000 feet on the north. Furthermore, at the time the writer last visited the St. Rémi district (July, 1918), the shaft on the property of the Canadian China Clay Conpamy, from which it is proposed to develop the deposits underground, was not yet completed, so that all that is known with regard to the extent of the kaolin deposits is the information obtained from trenching and stripping operations in scattered localities and from a few drill holes sunk on lots 5 and 6, range VI, south, Amherst township. For the foregoing reasons, the amounts of kaolin and associated materials known to be present in the district are small compared with the amounts that development work may eventually prove to be present. The following account of the extent of the deposits is, therefore, to a large degree, a statement of prospective possibilities rather than an estimate of amounts positively determined to exist.

The materials so far shown by development work to occur in the fracture zone traversing the belt of quartzite and garnet gneiss, are the following: white kaolin, discoloured kaolin, kaolinic quartzite, kaolinized granite (cornish stone), and kaolinized garnet gneiss.

Kaolin.

Kaolin leads ranging from a fraction of an inch up to 100 feet in width are known to be present in numerous localities throughout the fracture zone, but it is only on lots 5 and 6, range VI, south, Amherst township, that the superficial extent of the deposits has been determined by stripping operations. On these lots, kaolin has been shown to occur almost continuously in a zone of leads ranging from a few feet to 100 feet in width for a distance of over 1,400 feet. With the exception of the mass of kaolin adjacent to No. 1 pit at the north end of this zone (Map 1676), however, the outcrop of the kaolin in this locality is nearly everywhere highly discoloured and hence cannot be used as a filler in paper or for other purposes for which kaolin is most valuable, but is being employed as a fire-clay in the manufacture of fire-brick.

White Kaolin. On lot 5, range VI, south, Amherst township, on the property of the Canadian China Clay Company, there is a lead of white kaolin approximately 300 feet in length and from 15 to 40 feet in width that has been shown by a boring to descend to a depth of at least 150 feet. If it is assumed that this mass maintains its superficial dimensions at depth, there was originally present at this point approximately 10,000 tons of kaolin for every 50 feet to which the deposit descends. The data on which this estimate is based are the following:

Approximate length of deposit	300 feet
Approximate average width of deposit	25 feet
Average percentage of kaolin present	35 per cent
Depth of deposit	50 feet
Number of cubic feet of kaolin in 1 ton	13

The amount of kaolin above 50 feet now present in this deposit is, therefore, 10,000 tons less the amount removed by mining operations. This would include all the kaolin produced from the property (5,176 tons up to the end of 1917) and in addition the kaolin contained in the quartzite dumps from the washing plant.

It is possible that the discoloration in the outcrop of the southern part of the zone of kaolin leads on lots 5 and 6 disappears at depth and that white kaolin underlies the discoloured material. If development work should prove this to be the case and the zone maintains its superficial dimensions at depth, there would be present approximately 75,000 tons of white kaolin for every 50 feet of depth in this area. The data on which this estimate is based are the following:

Approximate length of zone	1,100 feet
Approximate average width of zone	60 feet
Assumed depth of deposit	50 feet
Average percentage of kaolin present	30 per cent
Number of cubic feet of kaolin in 1 ton	13

Discoloured Kaolin. As far as known at present, the discoloration in the kaolin occurs in only the southern part of the zone of deposits outcropping on lots 5 and 6, range VI, south, Amherst township, but it is possible that, here and there throughout the fracture zone, other masses of this character may be found as development work is continued.

It has been discovered that this discoloured kaolin, along with the quartzite grains and fragments which it contains, can be used as a fire-clay for the manufacture of fire-brick and information with regard to the amount of this material present in the district is, therefore, worthy of note. If the zone of discoloured kaolin exposed on lots 5 and 6 continues to a depth of 50 feet there would be present, on the basis of the data given above approximately 250,000 tons of this material. If the discoloration continues to a greater depth than 50 feet the quantity of fire-clay present would be proportionately increased, but the amount of white kaolin underlying the discoloured material would be correspondingly decreased.

Kaolinic Quartzite. It has already been pointed out that the zone of shattered quartzite in which the kaolin is found has a width of 1,000 feet and a length of approximately 7,000 feet, and that a sample taken continuously across a section of 133 feet through this shattered material contained on the average 11 per cent of kaolin. It is possible that there are considerable masses of quartzite in the shattered zone which are more or less unbroken and in which the kaolin content is much less than 11 per cent, nevertheless the areas of broken and granulated quartzite already known to be present in the fracture zone indicate that an enormous quantity of the highly kaolinic quartzite is present. Thus, in the area lying to the west of No. 1 pit on lot 5, range VI, south, Amherst township, sufficient development work has been performed to show that a mass of kaolinic quartzite at least 400 feet long by 200 feet wide is present, so that if this mass continues to a depth of only 50 feet, it contains over 300,000 tons of quartzite, and, if it continues to a depth of 150 feet—as the presence of kaolin to that depth beneath No. 1 pit would indicate—it contains 900,000 tons of quartzite. Furthermore, wherever the surface of the fracture zone has been laid bare by trenching or stripping operations the quartzite has been found to be broken in a manner similar to the mass adjacent to the No. 1 pit, and it is, therefore, reasonably certain that a considerable part of the fracture zone 7,000 feet long by 1,000 feet wide is underlain by this material.

Cornish Stone. In a small pit near the eastern margin of the fracture zone an altered granite having the chemical composition of cornish stone has been found. The bottom of this pit was filled with caved in material at the time the district was examined, and the cornish stone was, therefore, not observed in place by the writer. The extent of the deposit is wholly unknown, however.

Kaolinized Garnet Gneiss. Up to the present time kaolinized garnet gneiss has been encountered in only one locality within the zone of fracture and faulting traversing the belt of quartzite and garnet gneiss, namely, in the shaft now being sunk on the property of the Canadian China Clay Company; but the presence of numerous outcrops of garnet gneiss in the eastern half of lots 5 and 6, range VI, south, Amherst township, to the eastward of the fracture zone, indicates that kaolinized garnet gneiss zones that are unexposed may be present in the fracture zone. It is possible that the completely kaolinized parts of this material would serve as a fire-clay in the same manner that the discoloured kaolin and quartzite are being used.

Uses of Materials Contained in the Deposits.

Kaolin. Kaolin has long been the most important of the raw materials used in the ceramic industries and its use for this purpose is by far its principal industrial application. It is mixed with feldspar, china stone, quartz, bone ash, ball clay, soda, chalk, and other ingredients in varying proportions to form both the body and glazing of chinaware, porcelain, wall and floor tile, electrical insulators, enamelware, stoneware, etc. The other industrial uses to which it is applied include the following: as filler in the manufacture of paper, cotton, and other textiles; as a constituent of certain plasters, paints, and colouring agents; as face powder, as polishing powder, and as an ingredient in certain medicinal preparations.

Tests of the physical character of the china clay, made by J. Keele of the Mines Branch, are described by Mr. Keele as follows: "The washed kaolin requires 45 per cent of water for tempering. It has a fair amount of plasticity, but like all kaolin it works rather short and crumbly. The shrinkage on drying is 7 per cent.

Cone.	Fire shrinkage.	Absorption.
	Per cent.	Per cent.
010	3·0	34·3
06	3·6	34·3
1	4·5	32·0
5	9·3	20·0
9	11·3	17·0
34	Softens.	

This material has greater plasticity and higher shrinkages than most of the standard brands of washed kaolin or china clay. The samples for testing were taken from near the surface, but at deeper levels it is possible that the kaolin will not be so plastic and not shrink so much on drying or burning.[1]

Experiments made by Mr. Keele have shown that the mixture of white kaolin and quartzite composing the kaolin deposits can be mixed with the ordinary Pleistocene marine clay of St. Remi district to make fire-brick. These experiments are described by Mr. Keele as follows:

"The crude kaolin is highly refractory and when moulded into brick shapes and burned at the ordinary temperatures of burning fire-brick the

[1] "Preliminary report on the clay and shale deposits of the province of Quebec," Geol. Surv., Can., Dept. of Mines, Mem. 64, 1915, pp. 4 and 5.

resulting brick are rather soft and porous, with checked or cracked surfaces. A product like this would not stand transportation well, besides the brick would be structurally weak. It, therefore, seemed necessary to introduce some fluxes as a mixture in the kaolin in order to produce density and strength of body. The material selected was the marine clay occurring in the valley of Rouge river, which contains a high percentage of fluxing impurities and is consequently rather easily fusible.

The mixtures used in the test consisted of 10 to 20 per cent of marine clay and 90 to 80 per cent of crude kaolin. Bricks made from this mixture were burned in the fire-brick kilns at St. Johns, Quebec, at a temperature of 2,400 degrees F. The resulting brick had all the appearance of ordinary commercial fire-brick, being dense and strong.

A small portion of one of the bricks was placed in an electric kiln and raised to a temperature of 3,000 degrees F. without being sintered."

The crude, discoloured kaolin, owing to the impurities which it contains (see analysis, page 24) is less refractory than the white kaolin and can, therefore, be used as a fire-clay without the addition of Pleistocene clay as a flux. Experiments made with this material by Mr. Keele showed that it remained intact in a carbon resistance furnace at cone 25, but that it was rather short-grained and inclined to be weak in the raw state and shrank excessively when burned in a kiln.[1]

Kaolinic Wall Rock. The easily crushed kaolinic quartzite wall rock associated with the kaolin deposits may possibly be of greater commercial value than the kaolin deposits themselves, for this material can be used for the manufacture of silica brick of the ganister type, and when freed from the kaolin content is suitable for use in the manufacture of lime bonded silica brick, glass carborundum, and as a steel foundry sand.

An experiment made with the kaolinic wall rock to determine its suitability for the manufacture of silica brick of the ganister type is described by Mr. Keele in the following statement:

"The material was crushed to pass a 10-mesh screen and milled with a little water until it became somewhat cohesive. At this stage it could be moulded into brick shapes by hand, and re-pressed by machinery when partly dry. The bricklets were burned in a gas kiln to 1,300 degrees C. and afterwards in an electric resistance furnace to 1,530 degrees C., a small portion of one of the bricklets being finally raised to 1,650 degrees C. The bricklets burned to 1,530 degrees were hard and dense, and showed that a fused bond between the kaolin and quartz grains was effected.

Raising the temperature to 1,650 degrees changed the character of the material only slightly, there being no indication of failure through softening, and it would probably stand a temperature of 1,700 degrees just as effectively.

These results seem promising for such uses as puddling, malleable, cupola, and crucible furnaces, or for convertor linings and glass making furnaces."

A quantity of the crude, kaolinic wall rock was washed in the laboratory of the Mines Branch by Heber Cole, and a silica sand of the following composition was obtained:

SiO_2 99·25 per cent, Fe_2O_3 0·69 per cent, $AlSO_3$ 0·06 per cent.

A statement of the results of his experiments supplied the writer by Mr. Cole is as follows:

[1] Mines Branch, Dept. of Mines, Sum. Rept., 1916, pp. 106–7.

"The method of preparing this sample was to crush material in a dry pan so that it all passed through a 16-mesh screen. It was then washed in a running stream of water and the material passing through 100-mesh was collected separately. This fine material contained finely divided silica and the kaolin present in the crude rock. The analysis given above was of the material retained on the 100-mesh. A sample of this latter was submitted to one of the carborundum companies, who tested it and found it satisfactory for the manufacture of carborundum. In a proper commercial plant consisting of crushers, grinders, washers, hydraulic classifiers, and dryers, silica sand running well over 99 per cent silica should be easily produced economically and a product put on the market suitable for all the uses in which a high-class silica sand is required."

Equipment and Mining Methods.

The mining method employed on the property of the Canadian China Clay Company originally consisted in removing the overburden and wall rock by means of an aerial hoist and conveying the kaolin and associated quartzite to the washing plant in a 6-inch syphon. During the winter of [illegible], a steam shovel was employed in stripping the overburden from an area over 1,300 feet long and from 30 to 100 feet wide on lots 5 and 6, range VI, Amherst township, and at the time the writer visited the property in July, 1918, the discoloured kaolin from this area was being loaded into cars and shipped to Laprairie for the manufacture of fire-brick. A shaft was also being sunk at the west side of fracture zone on lot 6, through which it was proposed to mine the kaolin and kaolinic quartzite from underground workings.

The equipment on the property of the Canadian China Clay Company includes a washing plant (Plate II B) for the separation of the kaolin from the associated quartzite, an aerial hoist, compressor, drills, and other equipment necessary for mining operations; and the camp buildings required to accommodate the employees of the company.

The process used in the washing plant consists in passing the kaolin and its included quartzite through an agitator, then through a revolving screen, and finally through troughs from which the kaolin is conveyed to settling tanks. After the kaolin has settled the supernatant water is drained off, and the kaolin pumped into filter presses. From the filter the cakes of kaolin are conveyed on cars to drying sheds in the summer and to a kiln in winter.

A plant for crushing, washing, and classifying the quartzite wall rock was also being constructed on the property.

Production.

The production of china clay from the property of the Canadian China Clay Company has been as follows:

Year.	Tons.	Value.
1912	40	$ 520 00
1913	253	4,354 00
1914	1,000	9,000 00
1915	1,300	13,000 00
1916	1,750	17,500 00
1917	833	11,144 00

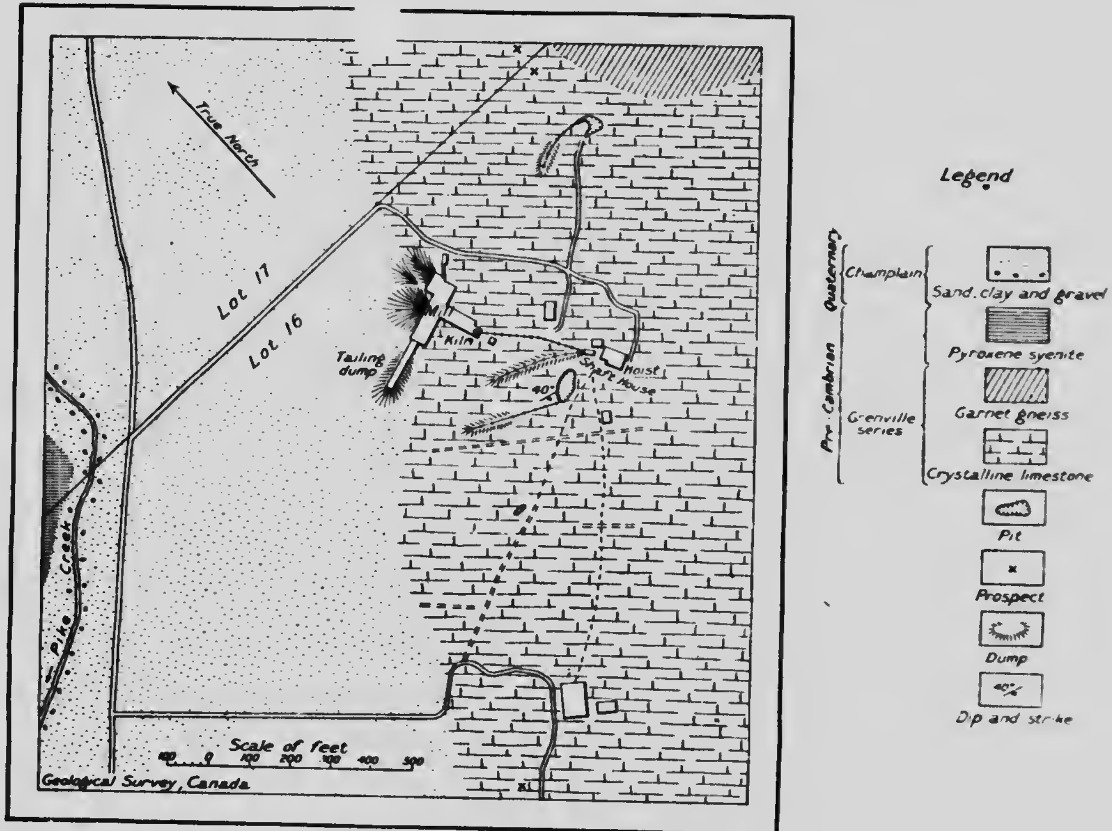


Figure 3. Diagram showing parts of lots 16 and 17, range VI, Amherst township, Quebec.

Lots 15, 16, and 17, range VI, Amherst township.

General Statement.

Throughout eastern Ontario and the southern Laurentians of Quebec, numerous deposits of graphite (from which graphite has been mined continuously or at intervals for many years) occur in association with the crystalline limestone member of the Grenville series. These deposits are similar in most respects and have probably originated in the same way, but the graphite composing them occurs, partly in disseminated form, partly in veins, and partly in aggregates, and the deposits are, therefore, regarded as belonging to different classes according to the particular forms in which the graphite occurs. Deposits of the disseminated and vein types are the common modes of occurrence of graphite, both in eastern Ontario and in Quebec. Deposits of the aggregate variety, on the other hand, have been observed by the writer in only two localities, on lots 9 and 10, range V, Grenville township (Keystone mine), and on lots 15, 16, and 17, range VI, Amherst township, described in this report.

History of Development.

Attention was first directed to the graphite deposits in Amherst township in 1907, when two prospectors, Messrs. P. Tetreault and H. Roy, acquired the mining rights to lots 15 and 16, range VI, Amherst township, from the Provincial Government of Quebec. In 1909 a company was organized in Montreal under the title "Graphite Limited," to take over the property, and development work was begun and was continued until 1912. During this time numerous prospect pits and trenches were excavated, and No. 1 shaft was sunk to a depth of 105 feet. The construction of a mill was commenced in 1912 and completed in 1913. In December of that year the company went into liquidation.

In the autumn of 1916 an English (Multipar) syndicate took an option on the property and opened a pit near the north boundary of lot 16; but, after a few weeks' operation, the option was dropped.

Geological Relationships.

On the east side of the northeasterly trending flat which extends along Pike creek on lots 15, 16, and 17, range VI, Amherst township, there is exposed a low, drift covered ridge underlain by crystalline limestone. In common with the Grenville limestone generally, this includes numerous masses of pyroxene granite, pyroxene syenite, and other rocks which presumably were originally intruded into the limestone as dykes, but were subsequently broken up by deformation into fragments. In places the limestone also contains masses of orthoclase, wollastonite, pyroxene, and other silicate minerals with which graphite in exceedingly coarse flakes is associated, and these masses constitute the graphite deposits.

Character of Deposits.

At the time the writer made his examination of the property the main pit was filled with water, so that the character of the deposits in the underground workings was not observed. The following description is, therefore, based mainly on observations at the surface in three localities, the opening at the top of the main pit, the pit opened by the Multipar syndicate near the north boundary of lot 16, and two small prospect pits situated a few hundred feet north of the south line of lot 17.

The main pit is situated a few feet from No. 1 shaft and is connected with the shaft in the underground workings. The excavation at the top of the shaft is 60 feet long by 30 feet wide, and the deep part of the opening is 30 feet long by 15 feet wide. The rock exposed is pyroxenic limestone containing numerous crumpled inclusions of fine grey pyroxene-granite and pyroxene-syenite. It was observed that at the south end of the pit a zone of graphitic wollastonite had been developed along the contact of an included igneous mass and that the east face of the pit a few feet farther to the north consisted of granite, from which the graphitic material had been mined away. At the north end of the pit a number of other inclusions surrounded by similar graphitic contact zones were also present.

The Multipar pit at the time the writer made his examination of the property was 120 feet long, 50 feet wide, and from 10 to 20 feet deep. On the west face of the opening a mass of rock approximately 10 feet wide and 5 feet high was exposed, consisting of syenite and wollastonite intervening between vertical leads or aggregates of graphite 3½ and 2 feet wide, respectively. The south face of the pit consisted mainly of rusty crystalline limestone striking north 70 degrees east (magnetic) and dipping 50 degrees to the southeast, but included dykes and masses of pyroxene syenite of considerable size in places. One of these at the west end of the face was traversed by irregular zones of graphitic wollastonite from a few inches to a foot in diameter. The rock exposed on the east face of the pit beneath the covering of boulder clay included a considerable proportion of graphitic wollastonite, but the ore rock was most irregular and the proportion of graphite contained in the ore rock exceedingly variable. The largest and richest continuous mass of the material exposed diagonally across the south end of the face, was 20 feet long and from 2 to 10 feet wide, and contained approximately 50 per cent of graphite. The central part of the face, except for a few narrow, irregular vein-like leads of graphite, was barren, consisting of an elongated mass of pyroxene granite above and of a fine-grained grey rock which, under the microscope, was found to consist of scapolite, wollastonite, and garnet beneath. The north face of the excavation was in bouldery drift entirely.

The pits on lot 17 are small prospect openings in the Grenville limestone which at that point strikes north 35 degrees east (magnetic), and dips 75 degrees to the southeast. The rock exposed in the faces of the pits is mainly limestone with the usual inclusions and zones or masses of graphitic silicates (Plate VII) developed in places on the margins of the inclusions. The largest single mass of graphite ore observed was 3 feet long by 1½ feet wide.

It would seem evident from the preceding observations that the graphite occurring in the St. Remi district is associated with masses and zones of lime silicate minerals developed as a result of the silication of Grenville limestone, and that the quantity of graphite in the deposits is approximately proportional to the amount of this material present. It is not possible to definitely estimate the proportions of graphite present in deposits of such irregularity, but it is certain that in the total area of exposed rock surface, at the top of the main pit, and in the pits on lot 17, the percentage of graphite present is much less than that contained in the lowest grade of ore that could possibly be profitably mined under present conditions of operation. It is probable, on the other hand, that the percentage of graphite contained in the exposed faces of the Multipar pit at the time this opening was examined, averaged 5 or even 10 per cent, and hence constituted an ore of workable grade, provided this average maintained itself throughout a rock mass of workable dimensions; but much additional development work is required before this can be established.

Mineralogy.

The character and relationships of the principal minerals comprising the St. Remi graphite deposits are as follows:

Graphite (Carbon). The graphite contained in the deposits occurs in part as minute hexagonal plates disseminated in calcite, but more abundantly in lamellar aggregates up to 2 or 3 inches in diameter distributed along zones of granulation and fracture in the wollastonite and other minerals of the deposit.

Wollastonite ($CaOSiO_2$, Lime 48·3, Silica 51·7 per cent). Wollastonite is the dominant mineral of the deposits. It occurs in pale, green-white, uniformly fibrous crystals from 1 inch to 10 inches in length, the interspaces between which are filled with calcite, pyroxene, orthoclase, and titanite. The crystals are commonly traversed by irregular fracture zones filled with calcite and graphite.

Diopside ($CaMg(SiO_3)_2$, Lime 25·9, Magnesia 18·5, Silica 55·6 per cent). The diopside is a glossy green variety occurring in short, thick, prismatic crystals from one-quarter inch to 2 inches in diameter. These exhibit a prominent cleavage parallel 001.

Titanite ($CaO\ TiO_2\ SiO_2$, Lime 28·6, Titanium Dioxide 40·8, Silica 30·6 per cent). Titanite is a common constituent embedded in the calcite which fills the interspaces between the wollastonite crystals. It occurs in flat, wedge-shaped, resinous brown crystals up to 3 inches in diameter. In some of the large crystals a fine, uniform cleavage is well developed.

Orthoclase (K_2O, $Al_2O_3\ 6SiO_2$, Potash 16·9, Alumina 18·4, Silica 64·7). Orthoclase occurs chiefly as tabular crystals scattered through the material filling the interstices between the wollastonite masses. At one point a crystal was observed embedded in the diopside. In the specimen shown in Plate VII a number of these tabular crystals are conspicuously developed.

Scapolite (a Calcium, Sodium, Chlor., Aluminium Silicate). The scapolite associated with the graphite deposits is a peculiar opaque grey vitreous variety. It occurs as rounded crystals up to an inch or more in diameter, completely enclosed by the wollastonite.

Calcite ($CaCO_3$, Lime 56·0, Carbon Dioxide 44·0). The calcite is a pale yellow green variety which fills the interspaces between the other minerals of the deposits.

Quartz (SiO_2). Quartz is not a common or conspicuous constituent of the deposits. It was observed in association with orthoclase, filling the interspaces between the wollastonite crystals.

Paragenesis.

The manner in which the minerals composing the St. Remi graphite deposits are intergrown with one another is similar in every respect to the relationships exhibited by the mineral constituents of igneous rocks, so that from these relationships the approximate order in which the various minerals completed their crystallization can be determined. Thus the occurrence of the scapolite as inclusions in the wollastonite indicates that this mineral completed its development before the wollastonite, whereas the occurrence of orthoclase, titanite, and other minerals in the interspaces between the wollastonite crystals indicates that these followed the wollastonite in their development. Similarly the occurrence of the graphite and calcite as a matrix around other minerals, and filling the fractures traversing the wollastonite, indicates that these minerals were among the last to be deposited. The approximated order in which the various minerals composing the deposits completed their development was, therefore, as follows: scapolite, wollastonite, orthoclase, titanite, diopside, graphite, and calcite.

Origin.

In a previous publication it has been pointed out that there are three hypotheses which have been suggested to account for the origin of the graphite occurring in southeastern Ontario and the southern Laurentians of Quebec: that they are recrystallized, carbonaceous material contained in the Grenville limestone; that they have been derived from igneous rocks intruded into the limestone; and that they have been formed from the carbon dioxide of the limestone by reduction.[1]

The character and relationships of the St. Remi graphite deposits indicate that the minerals associated with the graphite are the product resulting from the metamorphism of the Grenville limestone and that this metamorphism was effected by emanations derived from the granite and syenite, included in the limestone. This association of the graphite with a contact metamorphic deposit would seem to support the hypothesis that the graphite had been formed from the carbon of carbon dioxide, for large quantities of carbon dioxide would be set free at the points where the silications of the limestone occurred. It is likewise probable, however, if the graphite were derived from the igneous intrusives that it would be evolved in company with other emanations, and might be concentrated at the points where these emanations were most abundant, and hence where silication had occurred. On the other hand, if the graphite were derived from carbonaceous material deposited with the limestone, there is no apparent reason why it should be associated with contact metamorphic deposits. On the whole, therefore, the evidence afforded by the St. Remi deposits seems to be most favourable to its derivation from carbon dioxide, and least favourable to the sedimentary hypothesis.

Equipment.

The equipment on the property includes a compressor, boiler, hoists, and other machinery necessary for the mining of the ore, and a dry concentrating mill having a capacity of 100 tons per day.

The buildings on the property in addition to the mill include a boarding house having accommodation for seventy-five men, a manager's house, a shaft house, boiler house, barn, and storehouse.

[1] Trans. Can. Min. Inst., vol. 19, 1916, pp. 363-365.

CHAPTER V.

SUMMARY AND CONCLUSIONS.

The most important data with regard to the geology and mineral deposits of the St. Remi district, stated in summary form, are as follows:

PHYSIOGRAPHY.

The district lies within the dissected southern border of the great Laurentian plateau, which occupies the greater part of northeastern Canada and in the main is characterized by the minutely rugged topography of that great upland, but is distinguished from the normal plateau topography by the presence of flats of post-glacial marine clay and sand deposited in the bottoms of its major depressions up to elevations of over 700 feet above sea-level.

GEOLOGY.

With the exception of a single dyke of diabase of late Pre-Cambrian age and the unconsolidated Quaternary deposits, the rocks occurring in the St. Remi district belong to a basal Pre-Cambrian complex composed of three separate subdivisions, which, named in order of age from oldest to youngest, are as follows:

(1) A series of highly metamorphosed marine sediments, crystalline limestone, garnet-gneiss, and quartzite—the Grenville series.

(2) A group of igneous intrusives—gabbro, pyroxene syenite, anorthosite, etc.—the Buckingham series.

(3) Batholithic masses of porphyritic granite and syenite gneiss.

MINERAL DEPOSITS.

The materials of commercial value known to occur in the region are kaolin, discoloured kaolin, kaolinic quartzite, and graphite.

Kaolin and Kaolinic Quartzite.

In the southern part of range VI, Amherst township, a belt of Grenville quartzite occurs, which is traversed by a north-northwesterly trending zone of fracture and faulting approximately 1,000 feet wide, in which deposits of kaolin occur in zones up to 100 feet in width and over 1,400 feet in length.

The kaolin occurs within the fracture zone, partly as narrow leads following the planes of fracture and jointing, partly as the matrix enclosing broken fragments of quartzite, and partly as replacement deposits, large quantities of the quartzite having been carried away in solution and the kaolin deposited in its place, so that the original structures of the quartzite are preserved.

The occurrence of the kaolin in a fracture zone in which feldspar or other aluminous silicates are almost entirely absent, indicates that the mineral has not been developed in situ, but has been carried into the fracture zone from an extraneous source.

Conclusive evidence from which the origin of the kaolin deposits could be inferred was not obtained, some of the features observed pointing to a superficial origin and others indicating a derivation from a deep-seated source. If the deposits have been derived from a superficial source they presumably have been formed by the residual downward concentration of kaolin derived from either the dykes of granite and bands of garnet-gneiss associated with the quartzite, or from the adjoining granitic batholiths, or from both of these sources. On the other hand, if the deposits have been derived from a deep seated source they have presumably been formed by the alteration of feldspar contained in granite or syenite occurring along the lower parts of the fracture zone and have been carried upward and d[illegible] the upper parts of the zone by ascending thermal waters.

[illegible] quartzite-garnet gneiss belt in which the fracture zone occu[illegible]gely hidden beneath a mantle of boulder clay, the quantities of white kaolin, discoloured kaolin, and kaolinic quartzite present in association with the zone of fracture and faulting, is not even approximately known, but the wide extent of the zone, and the enormous size and abundance of the kaolin leads exposed in those parts of the outcrop of the zone so far laid bare by trenching and stripping operations indica[illegible] (see page 33) that there are good prospective possibilities for the discovery of enormous masses of these materials.

Graphite.

At the eastern end of lots 15, 16, and 17, range VI, Amherst township, a ridge of Grenville limestone occurs throughout which masses of pegmatite, pyroxene granite, and pyroxene syenite are included. Within the limestone adjacent to these included rock masses aggregates of wollastonite, diopside, scapolite, and other lime silicate minerals are developed; and throughout these aggregates graphite occurs abundantly in coarse flakes up to 2 inches in diameter.

The occurrence of these deposits in association with inclusions of igneous rock in the limestone and in some cases following the margin of the inclusions seems to indicate that they have been developed by the interaction of emanations from the igneous inclusions and the limestone.

The underground workings on the property were filled with water at the time the writer made his examination of the district and such evidence as was obtained with regard to the extent of the deposits was limited entirely to the surface openings. Although the proportion of graphite contained in small masses exposed in these excavations was as much as 50 per cent in places, the deposits for the most part were too irregular and discontinuous to be profitably mined.

PLATE II.

A. St. Remi flat and village of St. Remi, as seen from the Alsio ridge. (Page 4.)

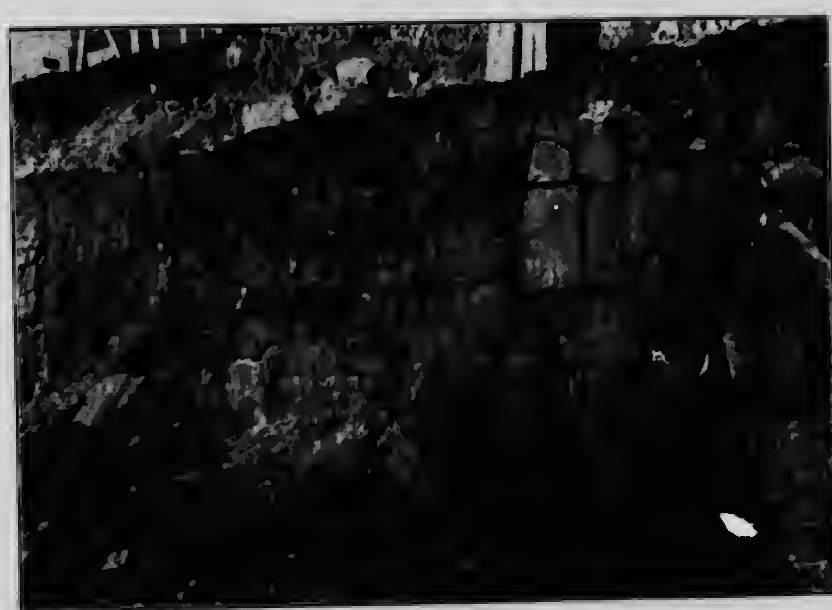
B. Washing plant, Canadian China Clay Company, lot V, range VI, south, Amherst township, Quebec. (Page 36.)

A. Crumpled, variegated garnet gneiss member of the Grenville series, lot 6, range VI, south, Amherst township, Quebec. (Page 8.)

B. Banded garnetiferous gabbro, lot 1, range II, Amherst township, Quebec. (Page 12.)

PLATE IV.

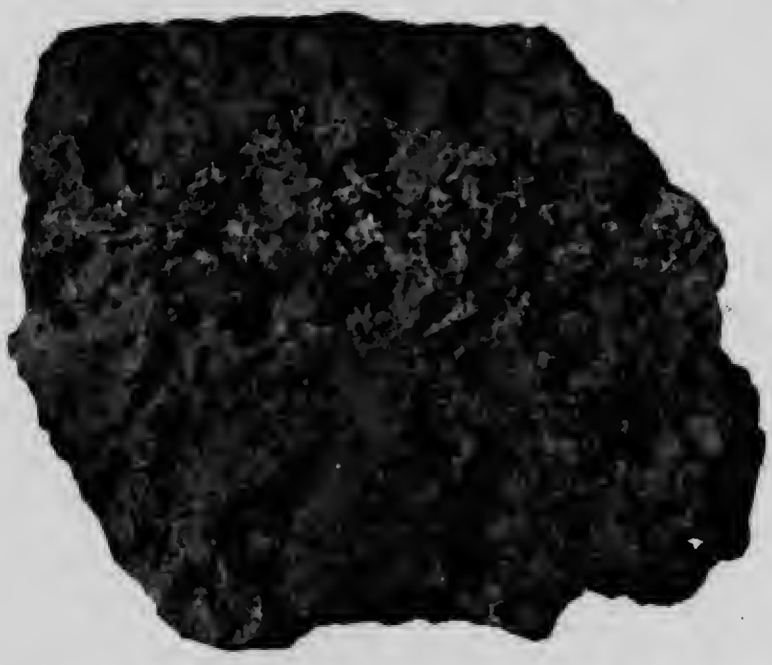
Variegated surface of garnetiferous gabbro, lot 1, range II, Amherst township, Quebec. (Page 12.)



A. Jointing in Grenville quartzite in fault zone, lot 5, range VI, south, Amherst township, Quebec. (Page 21.)

B. Fluted and slickensided surface of Grenville quartzite along fault zone, lot 5, range VI, south, Amherst township, Quebec. (Page 21.)

PLATE VI.



A. Pitted surface of quartzite bed showing the solvent action of solutions depositing the kaolin in the quartzite, lot 5, range VI, south, Amherst township, Quebec. (Page 23.)

B. Specimen from kaolin deposit, lot 6, range VI, south, Amherst township, Quebec. (Page 23.)

PLATE VII.

Aggregate of orthoclase, pyroxene, titanite, wollastonite, graphite, and calcite associated with graphite deposit, lot 17 range VI, Amherst township, Quebec. (Page 13.)
O, orthoclase; P, py[illegible]ne; W, wollastonite; G, graphite; C, calcite.

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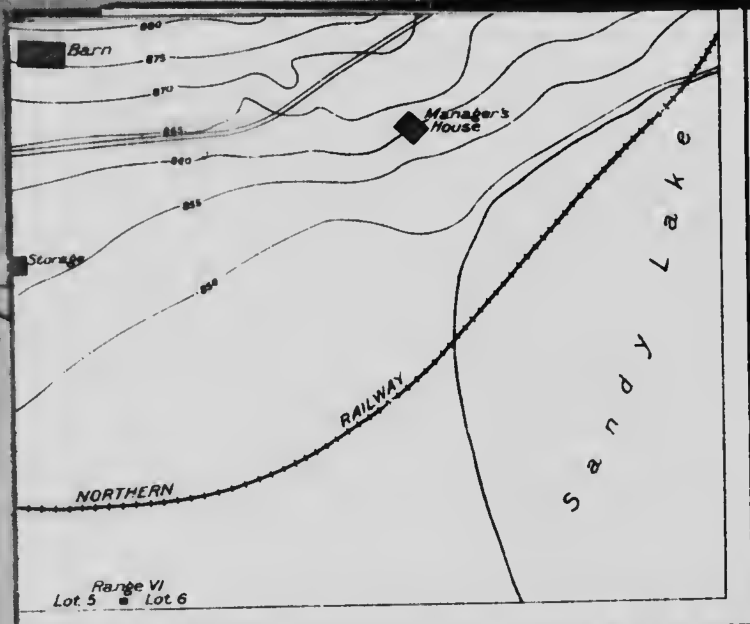

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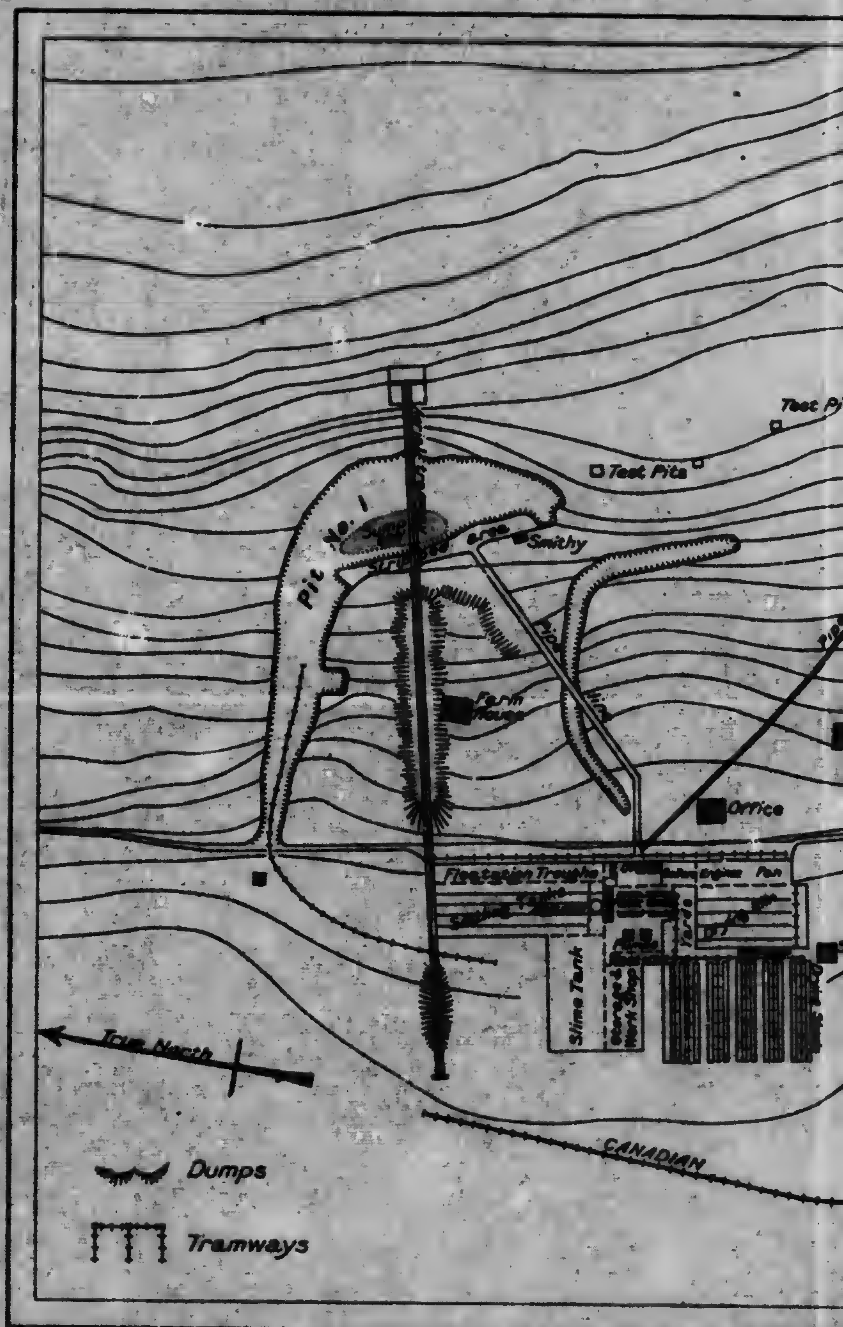

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Diagram shewing pits in ka

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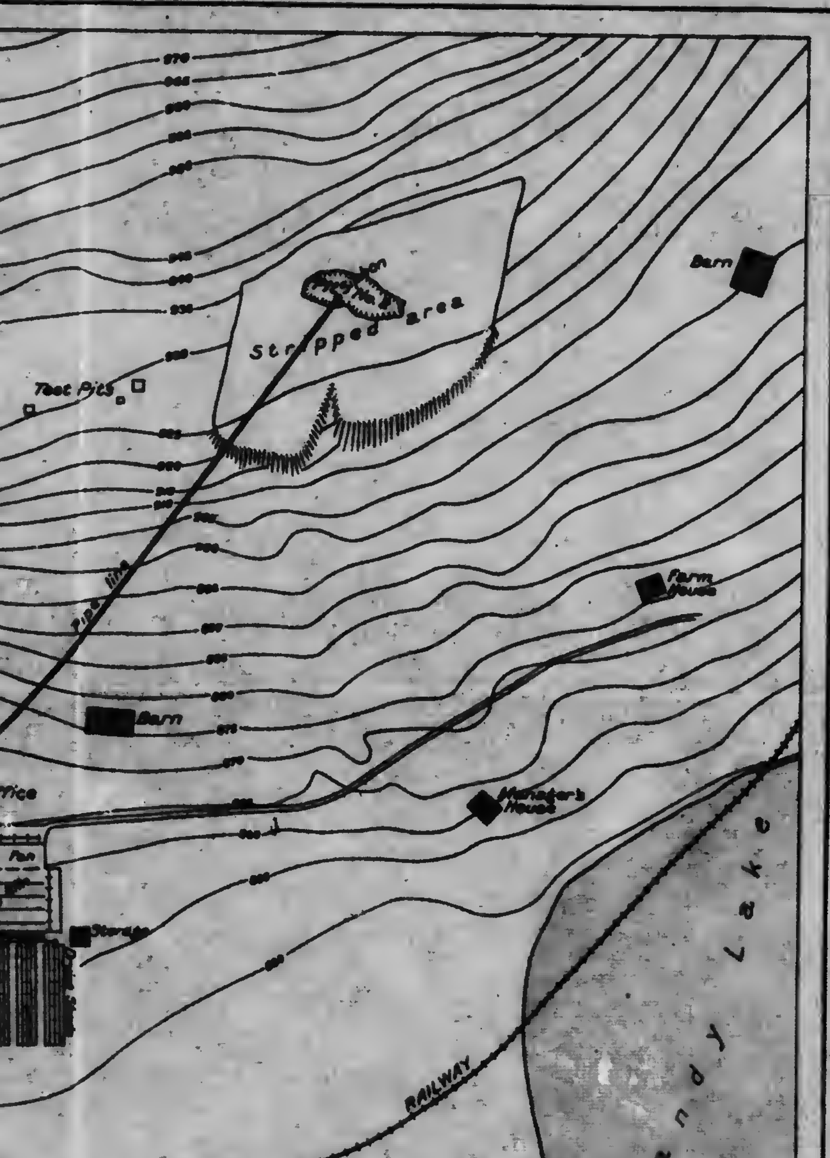
To accompany Memoir by M.E. Wilson.



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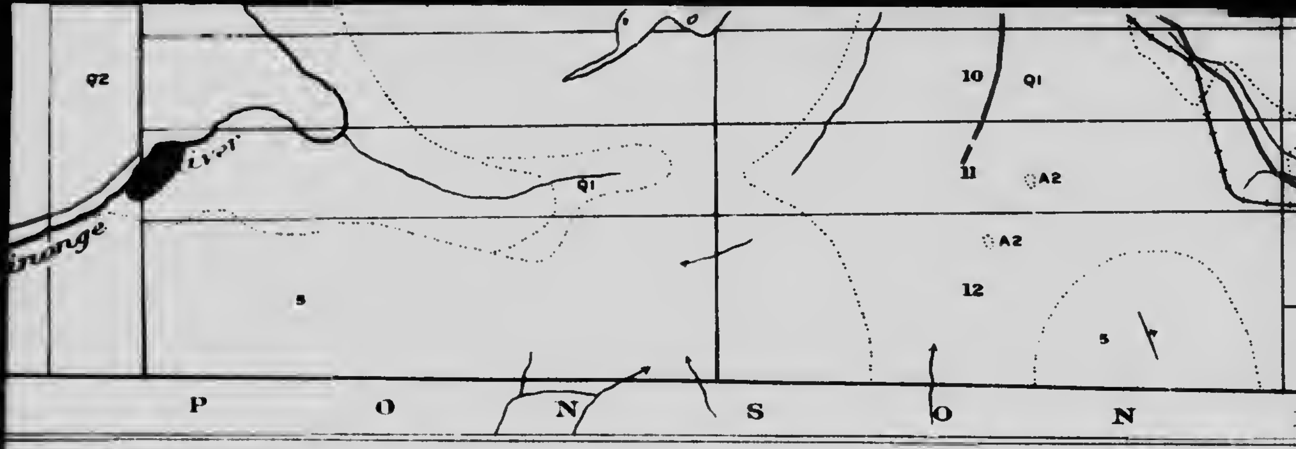

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Dep

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LEGEND

QUATERNARY
- CHAMPLAIN — Q2 — Clay, sand and gravel
- GLACIAL — Q1 — Boulder clay, boulders, sand and gravel

LATE PRE-CAMBRIAN
- 6 — Diabase
- 5 — Porphyritic granite-gneiss, syenite-gneiss, granodiorite-gneiss

EARLY PRE-CAMBRIAN
- Metamorphic pyroxenite
- BUCKINGHAM SERIES
  - Pyroxene syenite and pyroxene diorite
  - 2 — Gabbro
  - 1 — Buckingham series undifferentiated, pyroxene syenite, pyroxene diorite, pyroxenite (igneous)
- GRENVILLE
  - A3 — Garnet gneiss
  - A2 — Quartzite
  - Crystalline limestone

Symbols

Canada
Department of Mines
...N Burrell, Minister; R.G.McConnell, Deputy Minister.

GEOLOGICAL SURVEY
William McInnes Directing Geologist

Issued 1918

OUTLINE MAP

LEGEND

Streets, roads and buildings

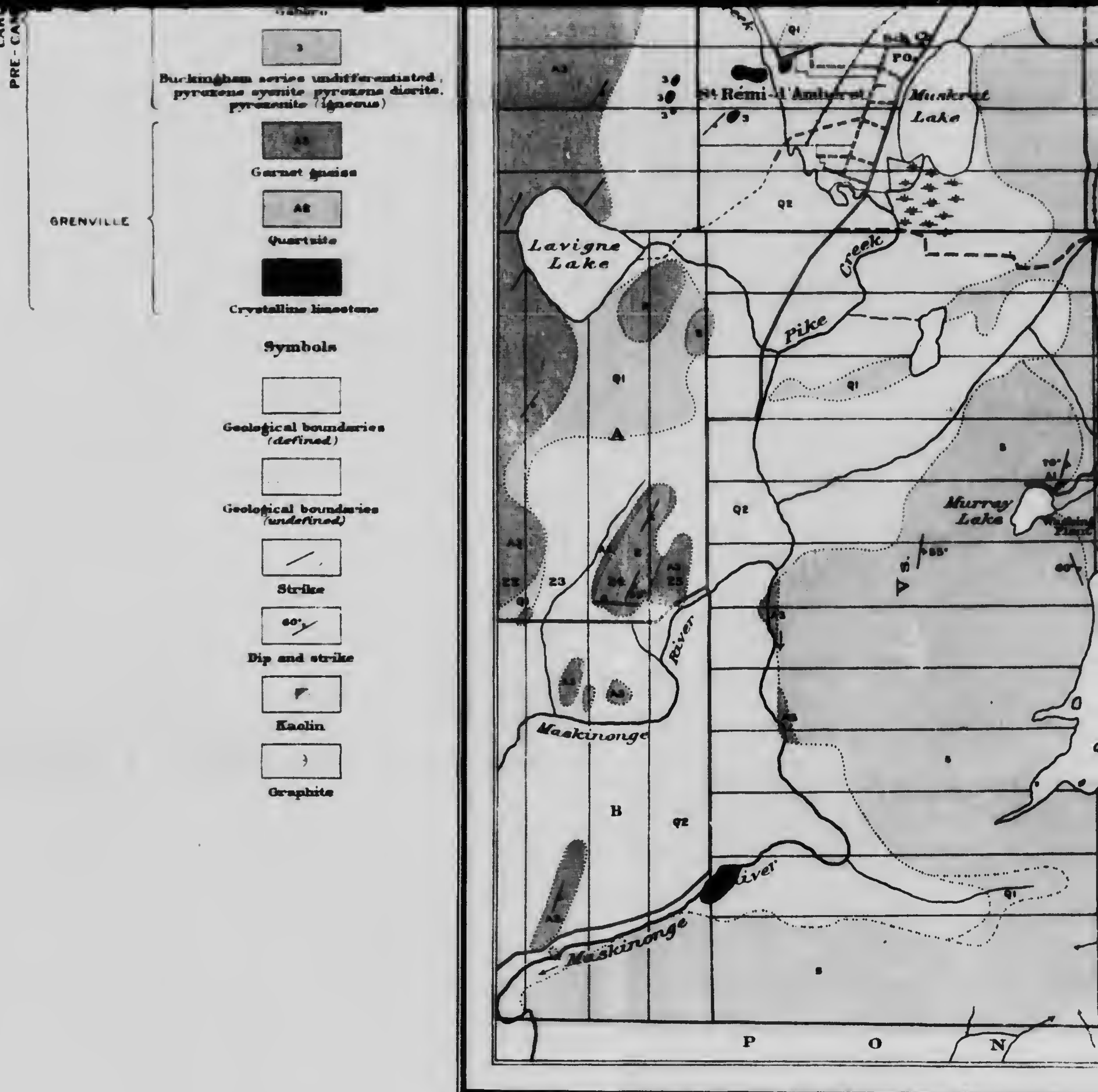
Private roads and roads not well defined

Trails

Railway

Proposed railway

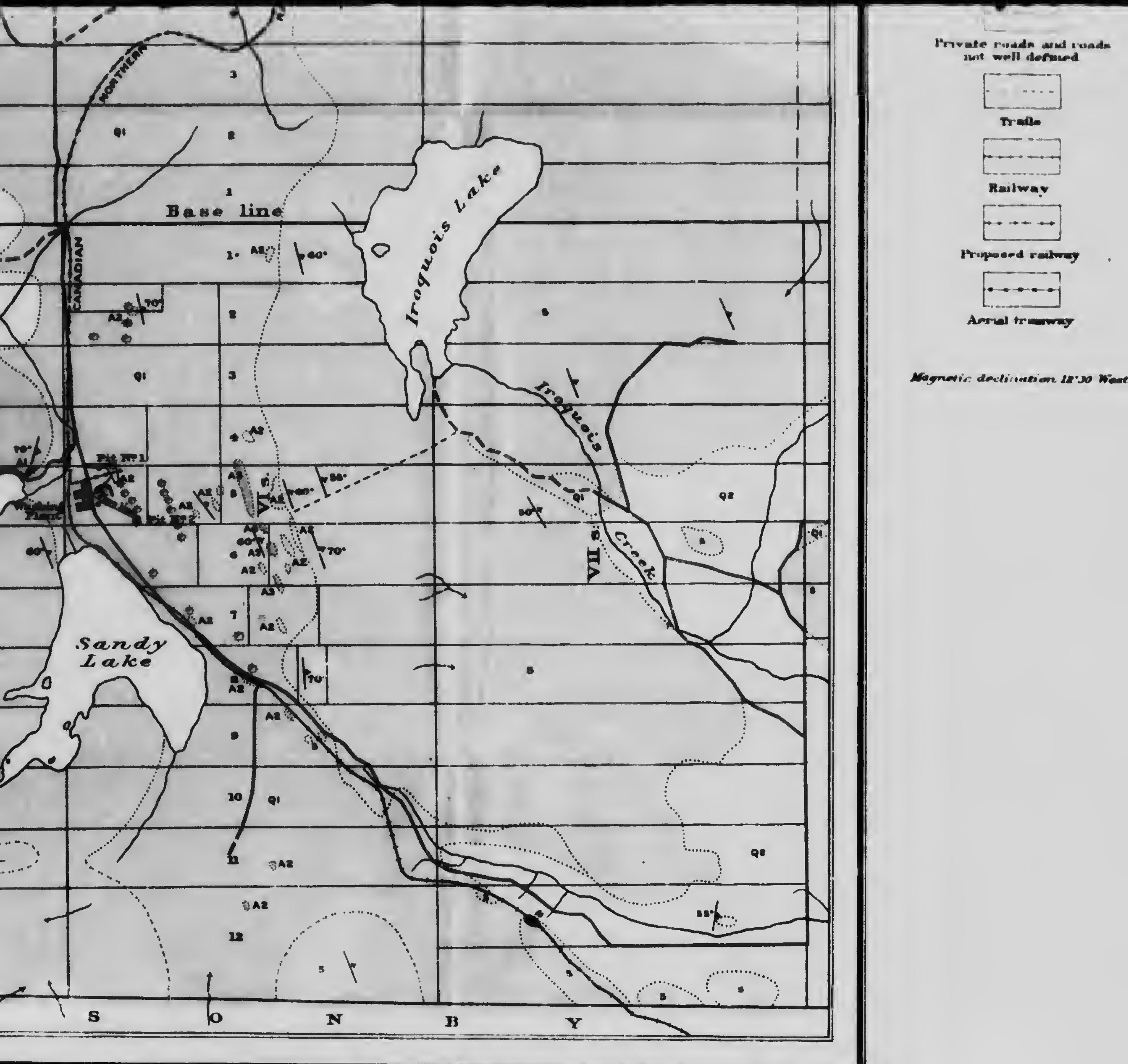
Aerial tramway



C.O.Senécal, *Geographer and Chief Draughtsman.*
A.McGregor, *Draughtsman.*

PORTION OF AMHERST TOV

To accompany Memoir by M.E.Wilson.



Publication Nº 1681

TOWNSHIP, LABELLE COUNTY, QUEBEC.

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