PETROLOGY OF SOME CRYSTALLINE ROCKS OF THE PERTH SHEET

ONTARIO

THE PETROLOGY OF SOME CRYSTALLINE ROCKS OF THE PERTH SHEET, ONTARIO.

by

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CONTENTS

MAPS AND ILLUSTRATIONS

PREFACE.

During the field season of 1930, the writer acted as an assistant on a Dominion Government Geological Survey party which was engaged in making a detail outcrop map of the Perth district covering parts of Lanark and Leeds counties, Southeastern Ontario. Towards the close of the season he was given the opportunity to collect specimens for detailed study.

The award of the LeRoy Memorial Fellowship to the writer made it possible for him to carry on the laboratory work at McGill University during the last six months.

The writer wishes to acknowledge his indebtedness to Dr. M.E. Wilson, Geological Survey of Canada, not only for suggestions as to a subject for a thesis but also for instructions in the field, for two maps accompanying this paper and for the loan of thirty-five thin sections.

The writer is further indebted to the professors of the Department of Geological Sciences at McGill University, more especially Dr.F.F. Osborne, for instruction, criticism and advice during the preparation of this paper.

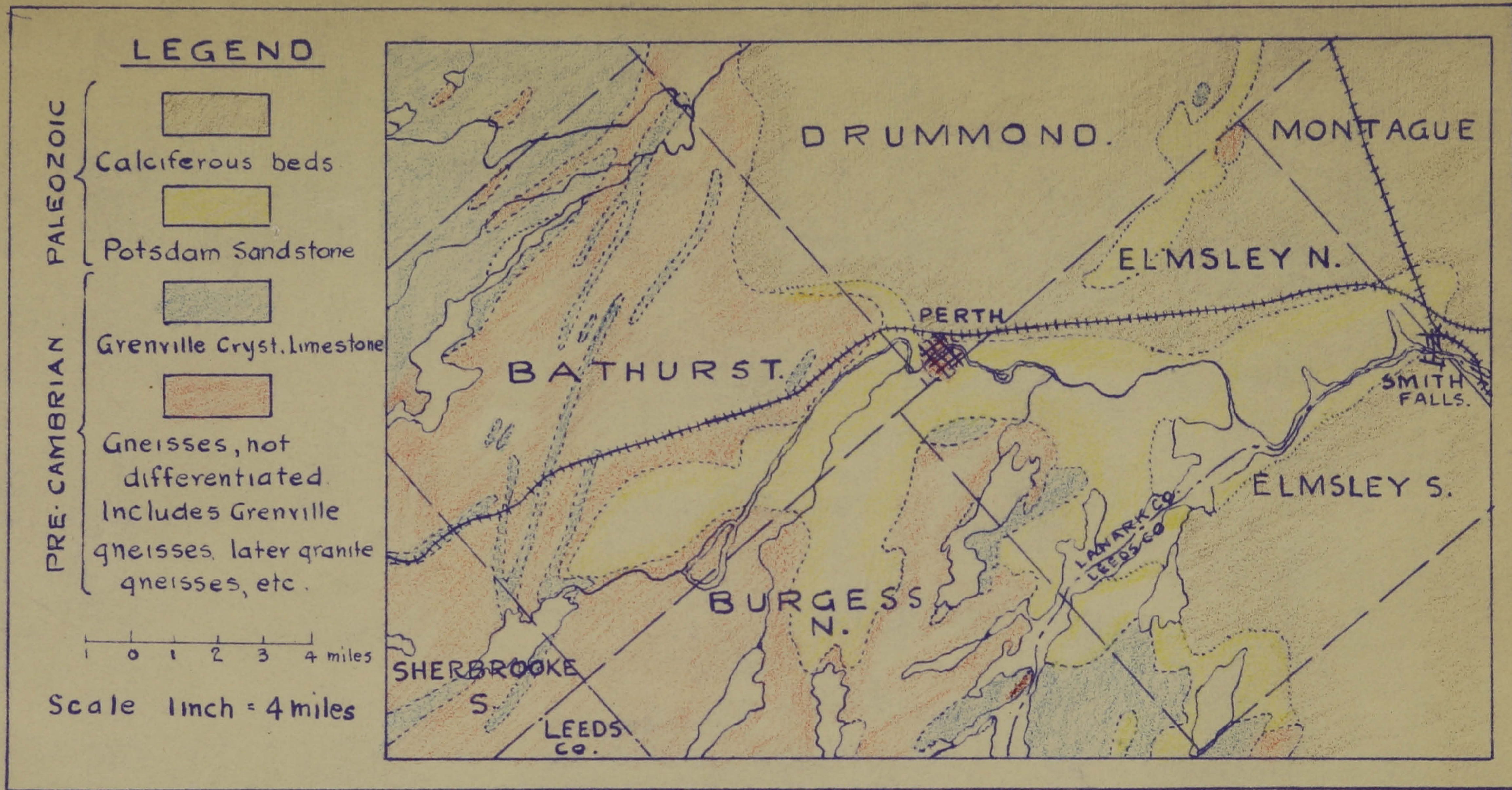
E.R. Wykes

INTRODUCTION.

It is the purpose of this paper to describe briefly the geology of the area covered by the Perth map-sheet, and to give a detailed account of certain Precambrian crystalline rocks occurring at two localities in the vicinity of Perth, namely (a) the Althorpe district which occupies a position between Christie Lake in Lanark county and Crosby Lake in Leeds county, Ontario, and (b) an area south of Black Creek, Burgess North township, Lanark County.

Part A. THE PERTH DISTRICT.

Farming has been the main occupation of the people since the region was first settled by soldiers demoblized after the War of 1812, but mining has been an important subsidiary industry. Lanark and Leeds counties have produced considerable apatite and phlogopite, and to a lesser extent feldspar, graphite, magnetite, calcite, and other economic minerals. Production, which was invariably on a small scale, has been so curtailed recently as to be almost negligible: it is fifteen years since any important mining has been done.



GENERAL DISTRIBUTION OF ROCKS IN THE PERTH DISTRICT.
(After Ells)

figure 1.

PREVIOUS WORK

The work of the Geological Survey of Canada commenced in 1843. Nine years later, in 1852, Alexander Murray[1] examined the crystalline rocks of Lanark and adjoining counties west of the Perth sheet. Murray was followed by Thomas MacFarlane[2] and H.G. Vennor[3] in 1865 to 1870. In 1901, R.W. Ells[4] published a map and a report covering parts of Renfrew, Lanark, Lennox and Addington, Frontenac and Carlton counties. The area covered by Ells is known as the Perth sheet No. 119. Small areas containing economic minerals, have been examined more recently.

GENERAL GEOLOGY

GENERAL DISTRIBUTION OF FORMATIONS.

Crystalline rocks characteristic of the Grenville subprovince crop out over about one-third of the Perth area. The rest is underlaid by flat-lying or gently-dipping Paleozoic formations, which occupy the eastern part of the sheet and extend as tongues over the crystalline rocks to the west. (Fig.1)

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[1] Murray, Alex., Geol. Surv. Can., Report of Progress, 1852-3, pp. 75-153.

[2] MacFarlane, Thos., Geol. Surv. Can., Report of Progress, 1863-6

[3] Vennor, H.G., Geol. Surv. Can., Report of Progress, 1870-1, pp. 309-315.

[4] Ells, R.W., Geol. Surv. Can., Annual Report, 1901, Part J pp. 1-79.

PHYSIOGRAPHY

The region is in two physiographic provinces, the St. Lawrence Lowlands and the Laurentian Plateau.

The part that is in the St. Lawrence Lowlands is essentially flat and not dissected by deep stream valleys; the relief does not exceed 50 feet, and the land slopes gently eastwards. That part in the Laurentian Plateau province is a comparatively rugged one with a northeast structural trend; the maximum relief is less than 300 feet, and the irregular topography is due to the erosion of an old peneplane developed on folded crystalline rocks.

The streams are adjusting themselves after the Pleistocene disarrangement and, consequently, the drainage is in a youthful stage. The eastern and flatter portion contains many swamps; lakes are abundant, and commonly occupy basins in old stream valleys. The lake basins were probably eroded by Pleistocene ice. Evidence of glaciation may be noted almost anywhere, but is most abundant in the west where, quite commonly, the mantle of drift is thin, and bare smooth ridges of gneiss with a steep side on the south occur at frequent intervals. Some of the outcrops are typical "roches moutonnées". Glacial striae are common on the Paleozoic sandstone.

BED ROCK

The formations in this district belong in three groups. (1) The Basal Complex. (2) Late Precambrian intrusives. (3) Paleozoic sedimentary rocks.

BASAL COMPLEX

Locally the Basal Complex, probably of early Precambrian age, is represented by four series: (a) highly metamorphosed sedimentary rocks -- the Grenville series; (b) igneous intrusives,-- pyroxene and amphibole diorites, gabbro etc., -- the Buckingham series; (c) batholithic-like intrusions, stocks and sills of granite, granite gneiss and syenite, intrusive into (a) and (b); (d) pegmatitic and aplitic dykes that cut (a), (b) and (c).

THE GRENVILLE SERIES

The oldest rocks in the district belong to the Grenville series, so called because they were first studied in Grenville township, Quebec, by Sir Wm. Logan. This series has a great areal extent in Canada. It outcrops along the southern border of the Canadian Shield from Georgian Bay on the west to beyond the St. Maurice River on the east and extends northward into the Canadian Shield. Adams and Barlow[x] have calculated a thickness of 94,000 feet for the Grenville series in Hastings county, Ontario. This thickness is very much greater than that observed elsewhere.

The Grenville series was deposited in the sea and consisted of alternating layers of limestone, shale and sandstone, which metamorphism has changed to white crystalline limestone, sillimanite-garnet gneiss, and

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[x] Adams, F.D., and Barlow, A.E., The Geology of the Haliburton and Bancroft areas; Geol. Surv. Can., Mem. 6, 1910.

quartzite. In places biotite-garnet gneiss and "rusty paragneiss" are found.

In the Perth district, crystalline limestone and garnet gneiss make up approximately ninety percent, and quartzite about ten percent, of the metamorphic rocks classified as Grenville. The crystalline limestone and garnet gneiss are present in about equal proportions. The quartzite occurs as narrow, discontinuous bands, commonly feldspathized and enclosed by garnet gneiss. Intrusive rocks have altered the limestone, in places, to "metamorphic pyroxenite" and "silicified diopside rock"; also it is possible that some of the fine-grained schistose rocks occurring in bands associated with the granite intrusives are intensely metamorphosed limestone. The crystalline limestones commonly contain disseminated graphite, diopside, phlogopite, and apatite.

Structural Relationships.

The Grenville series is cut by many granitic rocks which tend to obscure the structural relationships. This series strikes northeast. The dip of foliation or bedding is variable, but it commonly ranges from fifty to ninety degrees southeast.

The complicated folding of the Grenville series has rendered detailed structural interpretation difficult. Flow cleavage, commonly found in other Precambrian formations, is lacking. Drag folds present in some gneissic members may be useful in determining the attitude of folded beds, but it is improbable that reliable work could be done employing this structure alone.

The intense folding and association with coarse-grained igneous rocks indicate that the Grenville rocks were, at one time, deeply buried. The manner of deformation shown in some places suggests that the rocks were at least slightly plastic during folding, and it is inconceivable that the plasticity of the more siliceous rocks could be developed at the surface. The rocks now exposed at the surface are probably the roots of a great mountain range that has been eroded to a peneplane.

BUCKINGHAM SERIES*.

The Buckingham is a series of pyroxene-bearing rocks found widely distributed throughout the Precambrian Basal Complex. Its members range from peridotite to granite pegmatite, but gabbro, anorthosite, pyroxene diorite, and pyroxene syenite are the most common members. These rocks have a granular texture, commonly contain hypersthene, and are younger than the Grenville series but older than the batholithic intrusions of granite and syenite gneiss.

Although these rocks vary in composition from granites to gabbros, they have been grouped together

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* Wilson M.E., The Grenville Precambrian Subprovince Jour. Geol. 1925 P.395.
Geol. Surv. Can., Mem., 136, P. 28

because of their peculiar mineralogical composition, their evident genetic relationships to one another, and their approximate contemporaneity.

Rocks belonging to the Buckingham series are not prominent in the Perth district. However, mafic igneous rocks - diorite or gabbro - which are younger than the Grenville series and older than the batholithic intrusives occur, commonly as irregular bodies, throughout the areas occupied by the Basal Complex. The writer has no knowledge of the exact mineralogical composition of these mafic rocks, excepting the diorites that are included in the area described in detail under the heading "Mafic Inclusions in Granite Gneiss" (part B, page 18).

BATHOLITHIC INTRUSIVES.

Granites, granite gneisses, syenites and syenite gneisses make up about one half of the Basal Complex. These occur as sills, dykes, and batholiths and intrude the Grenville series and the Buckingham series. Where granite and syenite occur together the granite is younger than the syenite. No rock, either sedimentary or igneous, separating the syenite and granite has been found, and, thus, other criteria must be used to indicate whether these rocks belong to one or two periods of batholithic invasion. It is possible that they are widely separated in age, but it is more probable that they are facies of the same magma. The younger rock is more acidic than the older, which is the common order with successive intrusions of facies of subalkaline magma. Similarity in mineralogical and chemical character may be used to show the granite and syenite are from the same magma.(see p. 10).

Structural Relationships.

The strike and dip of foliation of the granite and syenite gneiss is parallel to that of the adjacent Grenville rocks. Wilson[x] believes that the conformity of the granite and syenite to the structure of the Grenville rocks "would seem to indicate almost conclusively that the magma underwent deformation during its consolidation. It is probably this relation that, --- led Logan and other early geologists --- to regard these igneous gneisses as sediments."

LATE PRECAMBRIAN INTRUSIVES.

In the Perth district, diabase dykes intrude the Basal Complex and are the youngest pre-Paleozoic rocks. By analogy with similar rocks on the north shore of Lake Huron,[1] these are considered late Precambrian.

[x] Op. Cit. P. 397.

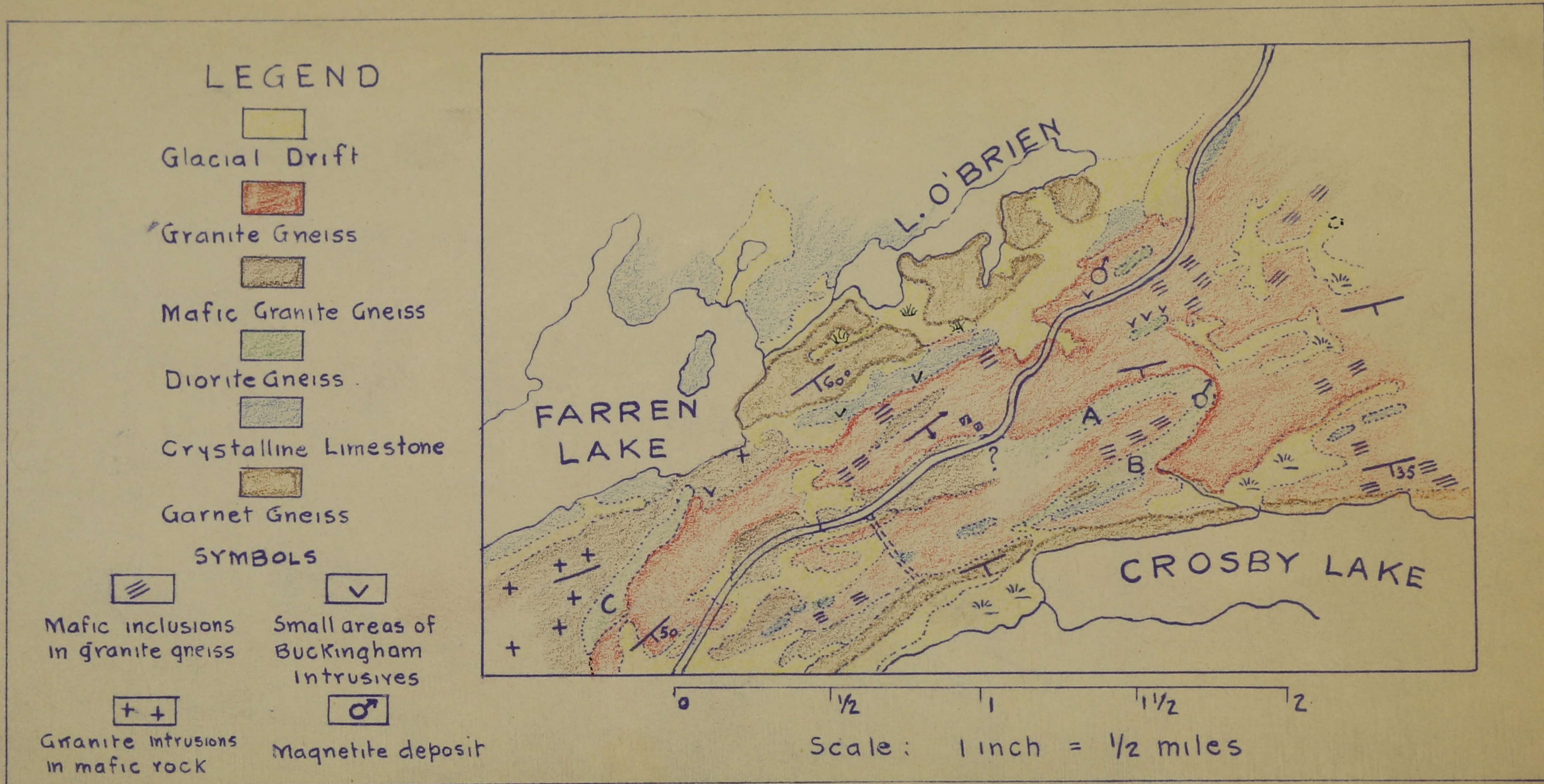
[1] Collins, W.H., North Shore of Lake Huron, Geol. Surv. Can., Mem. 143, 1925. P.P. 82-84.

PALEOZOIC FORMATIONS.

The Paleozoic formations consist of (a) a basal conglomerate composed of pebbles and cobbles up to six inches in diameter, imbedded in a grey limey matrix; (b) Potsdam sandstone, usually white, sugary and sometimes exhibiting bands stained by hematite; (c) Transitional or Theresa beds - sandy dolomites or limestones; (d) Beekmantown Dolomitic limestone.

Structure.

In general, the Paleozoic strata dip gently east. However, at the boundary between the Paleozoic strata and the Precambrian formations, the basal beds tend to conform to the minor irregularities of the erosion surface.



DISTRIBUTION OF ROCKS IN THE ALTHORPE DISTRICT.

figure 2.

Part B. THE ALTHORPE DISTRICT.

FOREWORD: Representatives of practically every member of the Basal Complex outcrop in the vicinity of Althorpe, which is a small community situated in South Sherbrooke township, Lanark county. A geological map of part of the district is shown in fig. 2.

One of the present problems in the Grenville subprovince is the correlation of the syenite and granite that intrude the Grenville series. Wherever these rocks occur together, the granite is younger than the syenite. No rock, either sedimentary or igneous, separating the syenite has been found, and thus other criteria must be used to indicate whether these rocks belong to one or to two periods of batholithic invasion.

An attempt is made to show that certain syenites and granites in the Althorpe district are consanguineous. The evidence used is the similarity in mineral composition and texture. It is suggested that further investigation should involve chemical analyses, for a similarity in chemical composition would undoubtedly aid in showing whether or not the syenites and granites are from the same magma.

The granite gneisses contain inclusions of pyroxene and amphibole gneisses. The position of the diorite gneisses in the geological time table and their mineralogical composition appear to be adequate evidence to show that these rocks are members of the Buckingham series.

GRANITE GNEISS

The granite gneiss is part of a huge batholith that invaded the Grenville and Buckingham series, probably in early Precambrian times. It forms possibly 70 percent of the rock outcrops in the Althorpe district, and good exposures may be observed in many places.

Gneissic Structure.

The structure of the granite gneiss tends to parallel that of the adjacent metamorphosed sedimentary rock. The field relations and petrographic evidence show that the structure is essentially primary, and that the magma was deformed prior to complete solidification. For instance, inclusions of foreign rock, which are but slightly deformed, occur in a matrix of well-banded gneiss. Also, it is seen that the microscopic texture of the gneiss is protoclastic.

PETROGRAPHY

Megascopically, the granite gneiss is composed of pink feldspar, quartz and dark minerals. In the hand specimen, the banded appearance is due to the parallel- dimensional arrangement of the mafic minerals and the presence of quartz in elongated lens- like individuals. The microscope shows that although the proportion of the several components varies, the minerals in all slides are similar. An amphibole near hastingsite is perhaps the most noteworthy constituent.

The average rock contains, in order of abundance;- Sodic feldspar (albite-oligoclase, Ab 90 An 10), quartz, microcline and orthoclase, amphibole, and biotite. Magnetite or apatite and sphene are present as accessory minerals.

A feature of the granite gneisses is the freshness of the feldspars. In Sherbrooke South township, Concession 1, Lot 9, the granite gneiss has an average mineral composition. The micoroscope shows that the rock is holocrystalline, uneven and medium-to coarse-grained, with a gneissic structure. Table 1 shows the mineralogical composition, and the distinguishing optical properties of the several constituents.

TABLE 1.

Sherbrooke South. Concession 1. Lot9.

Minerals	%	Distinguishing Optical Properties.
Quartz	25	ω greater than ref. ind. for Can. Balsam. Uniaxial and positive.
Microcline	20-25	Quadrille pattern. $\alpha' \wedge 010 = 2^{\circ}$; biax & negative. Indices well below that for Can. Balsam .
Plagioclase (albite)	35-45	$\alpha' \wedge 010 = 12\frac{1}{2}^{\circ}$. Optically positive. Index beta less than Can. Bals. 2V about 80° . Albite (Ab 91 An 9).
Amphibole (hastingsite)	10	Good cleav. $Z \wedge c = 28^{\circ}$; biax, but very small 2V. Opt. negative. Strong disp. - rho greater than upsilon. Pleoc. X. - pale yellow Z - blue green Y - olive green.
Pyroxene	1	Pale green with Opt. axis A disp. greater than that for B. Augite (diopsidic)
Accessories		Sphene, apatite, magnetite or ilmenite and epidote.

The amphibole and pyroxene are altered to a golden-yellow mineral with the optical properties of a member of the chlorite or "serpentine" group.

The quartz commonly occurs in irregular bands or zones made up of anhedra that do not exceed 3 mm. in diameter, and have no definite orientation. It also occurs as a filler in the interstices between the feldspar grains, and was evidently the last mineral to cease crystallizing.

The feldspars occur most abundantly in granular aggregates of small individuals of microcline, plagioclase and quartz. The individuals of microcline have an irregular outline but show well-developed characteristic twinning. The albite is inclined to be more regular in form than the microcline. It is twinned according to the albite law, and shows no zoning. Rarely, in places, both microcline and albite have developed to grains with a cross-section of two or three millimeters.

The feldspars are remarkably fresh and, with the exception of a trace of sericite and kaolin, secondary minerals after microcline or albite are absent.

The amphibole is present in grains that have a very ragged outline. The grains are about 5 mm. long and 1.5 mm. across. The indentations or hollows have been filled by quartz and feldspar. The optical data of this mineral suggest that it is an amphibole belonging to the Hastingsite group. The alteration product is a golden-yellow-coloured mineral with a fibrous appearance and a low negative birefringence. It is biaxial, has a small optic axial angle, and is non-pleochroic. These properties indicate that it is probably a member of the chlorite group. It apparently developed along the cleavage and fractures in the amphibole grains.

An opaque mineral that looks like magnetite in reflected light, is the most abundant accessory mineral. The grains are very irregular in outline, and commonly minute. The apatite is in crystals, but, as in the case of the sphene and epidote, the individuals are minute.

MAFIC GRANITE GNEISS.

One of the most puzzling features of the geology at Althorpe is a coarse-grained, somewhat distorted, mafic granite gneiss associated with the typical granite gneiss. This mafic gneiss is shown on the map in brown. Despite the fact that no sharp contact between the mafic rock and the pink granite gneiss is found, the rapid graduation from one so-called rock type to the other and the apparent dissimilarity in composition lead one to believe that the more mafic gneiss is older than the pink granite gneiss.

On the weathered surface, the mafic rock has a pepper and salt appearance due to the presence of pink feldspar, nodules of quartz and black mafic minerals. The structure is gneissic. In places metacrysts of amphibole and feldspar have developed and these cut across the alternating mafic and salic mineral-bands. These bands are very thin and not sharply defined.

Microscopic examination of some thin sections (Nos.1.11, Mc.11, Mc.12.) shows that the rock is composed essentially of 35 to 40 percent plagioclase with the optical properties of albite-oligoclase (Ab 90 An 10), 20 to 25 percent quartz, 15 to 25 percent amphibole with optical properties identical with that of the granite gneiss described above, 10 to 15 percent biotite, and a trace of orthoclase. The accessory minerals are apatite, magnetite, sphene and undeterminable needles in feldspar (which are possibly apatite.)

In other sections 35 to 40 percent amphibole is present. The quantity of apatite appears to increase with increase of mafic minerals.

The quartz occurs mainly as irregular grains segregated to form indefinite bands bounded by a granulated aggregation of all the rock components. The granulated areas are composed mostly of quartz and feldspar, but in places, these minerals are subordinate to amphibole and biotite, apparently depending on the relative location of the feldspathic or the mafic bands. One or two large grains of plagioclase occur here and there. The orthoclase is microperthitically intergrown with laths or lenticles of plagioclase in the ratio Or: Pl :: 4: 1. Secondary minerals after the feldapars are absent.

The amphibole and biotite occur mainly as broken fragments with an irregular outline, varying in size from minute individuals to grains 5 mm. long and 4 or 5 mm. wide.

The accessory minerals are commonly associated with the femic minerals. Magnetite is poikilitically included in the amphibole.

Alteration products of the mafic minerals are practically absent. Magnetite shows slight alteration to hematite.

Microscopic examination shows that the pink granite gneiss surrounding the mafic rock is similar in mineralogical composition. On lot 11, concession 1, Sherbrooke South township, the associated pink gneiss contains:

quartz - 20-25 percent
albite-oligoclase - 25-30 percent
amphibole - 10-15 percent
(hastingsite)
biotite - 5-10 percent.

The accessory minerals of this rock are sphene in irregular grains and a trace of magnetite and apatite. Alteration products are entirely absent.

The microscopic structure is similar to the of the mafic gneiss.

At lot 9,concession 1, the pink granite gneiss bordering the mafic rock is fine-grained and contains bands about one-eighth of an inch wide composed of mafic minerals. Due to the straightness of the mafic bands, the rock has a "cleavage" that compares favourably with that in many schists. The mineralogical composition is almost identical.with that of the pink gneiss at lot 11 in the same concession. The microscope shows, however, that this rock has undergone cataclastic deformation. The mafic minerals are definitely oriented in one direction and occur in narrow straight bands bounded by granulated aggregates of feldspar and quartz. The grains of biotite and amphibole are small and irregular in outline and are evidently broken crystals.

RELATIONSHIPS OF THE GRANITE GNEISS AND MAFIC GRANITE.

A microscopic examination shows that the mineral components of the mafic rock and suurounding granite gneiss are essentially the same: an amphibole near hastingsite is present in all the thin sections; the feldspars are of the same composition, and quartz is an abundant constituent. The structure of both rocks is similar . These data are a good indication that the rocks are closely related and that they are merely facies of the same magma. No explanation of why the magma should form two such facies is evident in the field.

MAFIC INCLUSIONS IN GRANITE GNEISS

Mafic inclusions are not restricted to this district but are common in granite intrusives throughout the whole of the Grenville subprovince. Their relationships to the enclosing rock has been a problem wherever the Grenville subprovince has bee geologically examined.

The rock constituting these inclusions is invariably more basic in appearance than the enclosing granite gneiss and commonly shows a distinct foliation which coincides in direction with that of the granite gneiss.

The character of the inclusions varies considerably. The following types have been observed: (1) Grey, coarse-grained diorite or gabbro definitely cut by the granite gneiss, and in places in areas large enough to be mapped. (2) Fine-grained amphibolites and pyroxene-diorite gneiss. (3) Schists containing abundant biotite. The second and third types commonly occur as straight, narrow bands from a fraction of an inch to a few feet wide or as small, irregularly-bounded masses in the prevailing granitic rock. On account of the map-scale, their presence can be indicated only by a symbol.

Although it is not evident from a study of the geological map, it was noted in the field that wherever intrusive granitic rocks are in contact with limestone or garnet gneiss, they almost invariably contain a relatively greater percentage of mafic inclusions. These are commonly in the form of straight, narrow bands of medium-to fine-grained amphibole.

What significance this relationship has on the origin of the mafic inclusions is not dealt with in this paper.

PETROGRAPHY.

In an area a short distance to the east of that included in the map of the Althorpe district, on lots 23 and 24, concession 1 Bathurst township, pink granite gneiss predominates and contains inclusions of dark grey, coarse-grained rock, that are inclined to be gneissic although they do not show the straight banding characteristics of the enclosing granite gneiss. The inclusions are irregular in shape, and occur as disconnected areas ranging from a few to hundreds of square feet. They show sharp contacts with the granite which encloses them. In places, offshoots of the granite intrude the inclusions in an irregular, criss-cross manner.

~~the inclusions in an~~ irregular, criss-cross manner.

The granite gneiss is heterogeneous: for a few feet tranverse to the foliation, it is comparatively free from mafic minerals, then changes gradually to rock which contains seven or eight percent mafic minerals.

It is believed that this change in composition of the granite is not due to the inclusions of the mafic rock; there is no absolute evidence to substantiate this belief however.

Megascopically, the banded appearance of the granitic rock is due to (a) the parallel-dimensional arrangement of the mafic minerals; (b) the presence of quartz in elongated lens-like individuals.

The dark grey, coarse-grained inclusions are diorite. The granularity of this diorite is uniform and microscopic examination shows no change in its character or composition at the contact with the granite gneiss.

Fine-grained quartz-feldspar pegmatite dykes, averaging six or seven inches in width and containing feldspar crystals three-quarters of an inch across, cut both the granite gneiss and mafic inclusions.

The regional strike is north 52° east and the foliation dips 55° southeast.

Microscopic examination of the Diorite inclusions.

Holocrystalline, coarse and even granularity; gneissic structure.

Minerals.	%	Distinguishing Optical Properties.
plagioclase (andesine)	50	Ref. Ind. α =1.545, γ =1.555 Opt. negative. $\alpha' \wedge 010 = 19\frac{1}{2}^{\circ}$. Andesine 35 mol % An.
pyroxene (augite)	25	$Z \wedge c=45^{\circ}$, Opt. positive, 2 Vabt. 60°. The dispersion, rho greater than upsilon, is stronger for axis B than axis A- (Ferrifrous?) Very pale green.
amphibole (may be secondary)	15	$Z \wedge c=25^{\circ}$ 2V large and optic. neg., weak disp. Pleoc: Y; olive green, greater than Z-blue green, greater than X, yellow.
biotite	7	Straight extinct. Quasi-uniaxial and neg.

accessory minerals:- apatite, magnetite, and sphene.

alteration prods.:- calcite, hematite, sericite, chlorite.

The andesine occurs as elongated distorted grains the albite twinning making remarkably evident the distortion. In general, the grains are large and show good outline, but cataclasis has reduced the size in places. Alteration to a mass of sericite, calcite and chlorite is prominent; the commencement of alteration appears to be along fractures in the feldspar. Augite, probably ferriferous, is present in large, commonly idiomorphic crystals, having no common orientation. As shown in Fig. 4, it is peculiarly associated with amphibole. The pyroxene is

Fig. 4. Pyroxene (P), with a reaction rim of amphibole (A). (B)-biotite. (a)- amphibole. X14

edged with and traversed by thin, disconnected bands or strips of hornblende which shows definite amphibole cleavage. These cleavage lines do not coincide with those of the augite and the traversing strips are at an angle of 40 to the augite cleavage. The augite shows schiller structure, the minute patches, possibly of magnetite, being in line with the amphibole strips.

It may be noted that the amphibole has very different properties from those determined in the hastingsite of the Althorpe granite.

Much biotite is poikilitically included

in the pyroxene and amphibole.

The accessory minerals constitute about 2 percent of the rock. Hematite is an alteration product of magnetite.

The pyroxene diorite has every appearance of an igneous rock, for although it is gneissic, the uniformity of the feldspars, the absence of quartz and scapolite, and the presence of idiomorphic crystals are criteria which distinguish it from amphibole- and pyroxene-rich metamorphic rocks of sedimentary origin.

This rock is classified as a member of the Buckingham series, despite the fact that it does not contain characteristic hypersthene. It has a similar mineral composition to the pyroxene diorite of the Arnprior district which Wilson[x] classed as Buckingham.

Granite Gneiss Surrounding the Diorite.

Thin sections of the granite gneiss show that the mafic minerals have been almost entirely altered to chlorite. A trace of amphibole remains, which cannot be precisely determined optically, but many of its properties resemble those of hastingsite. The gneiss is holocrystalline, has a coarse uneven granularity, and a protoclastic texture.

The composition is essentially:-

quartz	--	35 percent
microcline	--	30 to 40 percent
albite (ab 90 an 10)	--	5 to 10 "
amphibole	--	trace
muscovite	--	trace

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x The Arnprior-Maniwaki Area, Geol. Surv. Can., Mem. 136, 1924, p. 29.

Sphene and apatite make up about 5 and 2 percent of the rock respectively. A trace of magnetite is also present.

About 8 percent of the rock is a greenish-yellow chlorite. This is impregnated with quartz and feldspar and is commonly associated with magnetite. From its form, it is undoubtedly pseudomorphic after amphibole. Calcite is also present as a secondary mineral. Quartz occurs in bands made up of irregular grains having no definite orientations, and showing no strain shadows. A band is commonly interrupted by an area composed of granulated microcline, albite and quartz.

The microcline is the most abundant constituent, in aggregates of granulated feldspar and quartz, but a few relatively large grains occur. The "quadrille" pattern, characteristic of microcline is well developed (but more perfectly in the smaller grains). The large individuals of microcline are observed to be commonly microperthitically intergrown with albite. The albite occurs as disconnected parallel lenticles, that can be seen only by employing the high power objective.

The albite is twinned according to the albite law. It does not occur in large grains and appears to have crystallized simultaneously with microcline.

Sphene occurs as elongnated grains having irregular outline and good parting. The apatite individuals are commonly very irregular in outline.

A mineral, believed to be apatite, is present in needle-like inclusions in many of the quartz grains; these are so small that they could not be determined with certainty.

The quartz has been segregated into lenticular masses which have been somewhat granulated subsequently and also forms a ground mass for the granulated feldspar and mafic minerals. This texture is typically protoclastic and may be ascribed to the movement of the partially consolidated rock-mass following the separation of the feldspar but before the separation of the quartz. In this case the segregated quartz has been somewhat granulated subsequent to solidification, indicating that movement continued over a long period of time.

On lots 12 and 13, concession 1, Sherbrooke South township, Lanark county and lot 27 concession 4 Crosby township, Leeds county, diorite gneisses are included in the granite gneiss described on page 12 .The features that distinguish these inclusions are as follows: (a) composition essentially the same as the coarse-grained diorite except that amphibole constitutes 30 percent of the rock section, and pyroxene 7 percent. (b) There is a marked parallel orientation of the amphibole and pyroxene grains. (c) The rock is very fine-grained. (d) The diorite gneiss contains inclusions of garnet gneiss of Grenville age. The data indicate that this mafic rock should be classed as a member of the Buckingham series.

McCOY SYENITE.

The McCoy Syenite occurs to the east of Althorpe along Crosby road and is not shown on the accompanying geological map. The properties which distinguish this rock from the granite gneiss in the field are as follows: (a) The syenite is not foliated, or only slightly so. (b) On the fresh surface, the feldspars are commonly so dark in colour, that the rock has the appearance of an anorthosite. (c) Free quartz cannot be distinguished in the hand specimen. (The granite gneiss invariably contains pink or flesh coloured feldspar and a high percentage of free quartz).

Fine-grained pink quartz-syenite intrudes the McCoy syenite. The mineralogical composition and texture of the syenite and quartz-syenite indicate that these two rocks are facies of the same parent magma. The main aim, however, is to show whether or not it may be concluded that the Althorpe granite gneiss and the McCoy syenite are consanguineous.

PETROGRAPHY.

McCoy Syenite. The rock is composed essentially of:

oligoclase (Ab82 An18)	-----	50 to 60 percent.
microcline, orthoclase	------------	15 percent
amphibole (near hastingsite)	---	15 to 20 percent
pyroxene	-----------	10 percent

Biotite is commonly abundant but may be a secondary mineral; 2 to 3 percent quartz is present in some slides and the accessory minerals, sphene, apatite and magnetite, were found in all thin sections.

In general, the texture may be called hypidiomorphic. In detail, the larger mineral components are very irregular in outline and commonly show a fragmental zone around the edges, undoubtedly caused by crushing. A peculiar feature present in all the sections examined is the relationship between the microcline or orthoclase and the oligoclase: the microcline or orthoclase occurs as very irregular patch-like inclusions in a matrix of oligoclase (see Fig. 5). This is a rare type of

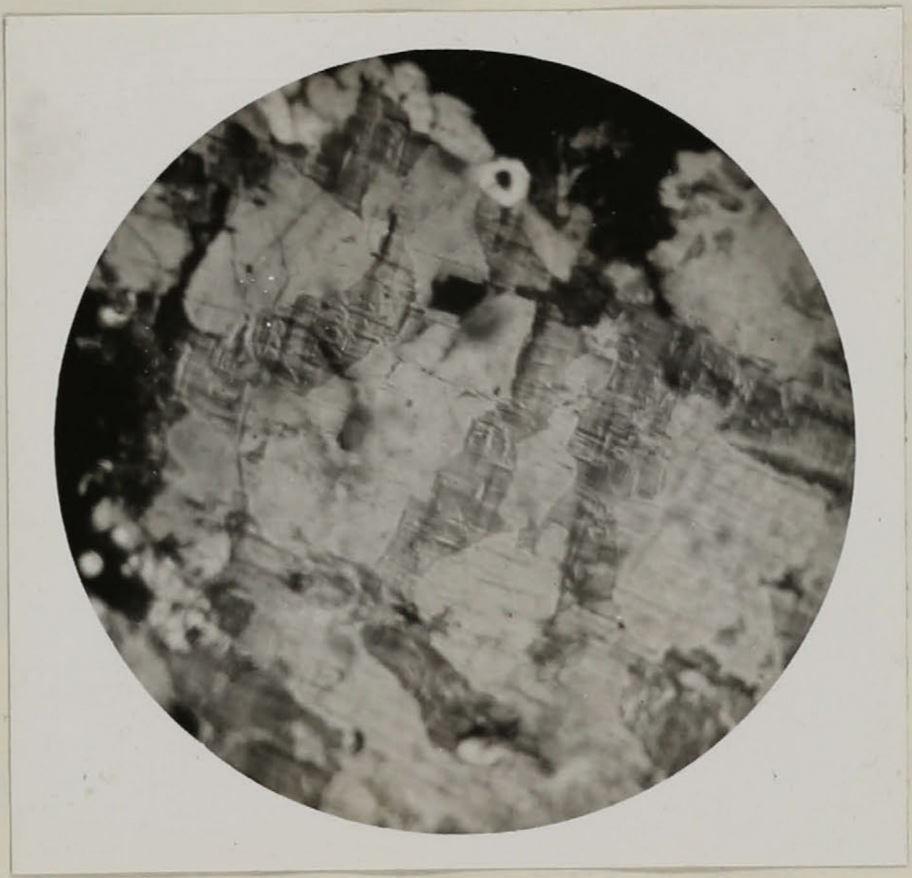
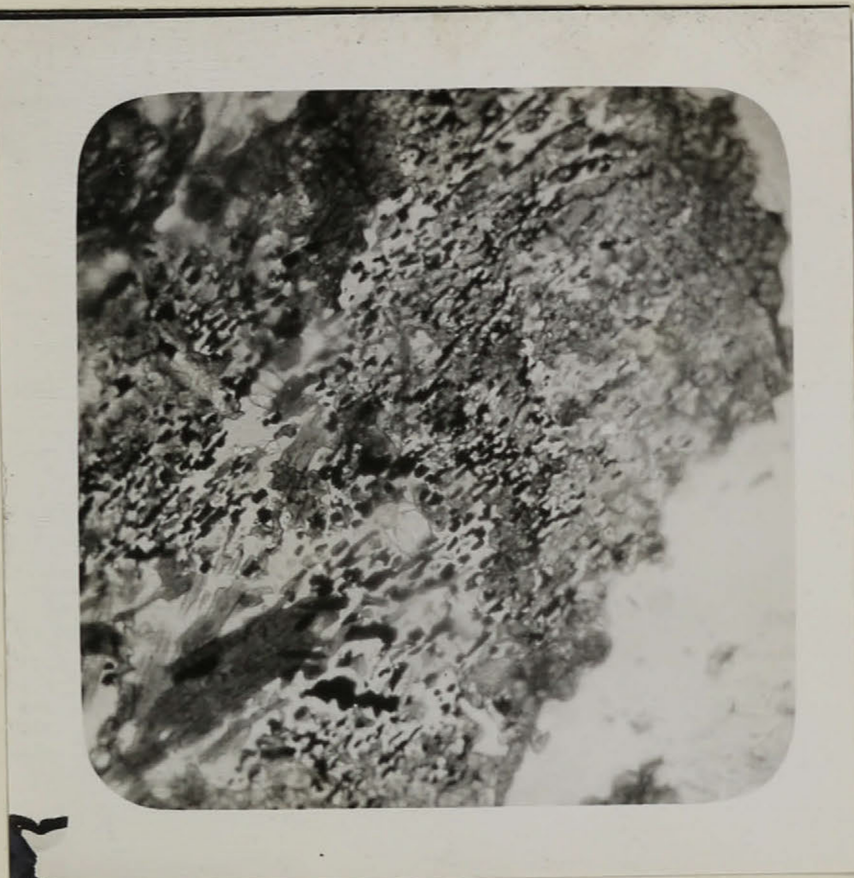


Fig. 5. Antiperthite. Microcline with quadrille pattern, intergrown with oligoclase (light)

antiperthitic (hyperperthitic) structure which may be due to the unmixing or "exsolution" of a supersaturated solid solution*. The oligoclase is altered to calcite and sericite along the cleavage, but these alteration products terminate abruptly at the contact between the potassic feldspar and the oligoclase.

It is evident that pyroxene was at one time a prominent constituent of the rock, but even in the freshest rocks, this pyroxene is almost entirely altered to an aggregate of iron ore, quartz, biotite, chlorite, calcite, and possibly amphibole. (See figures 6 and 7).



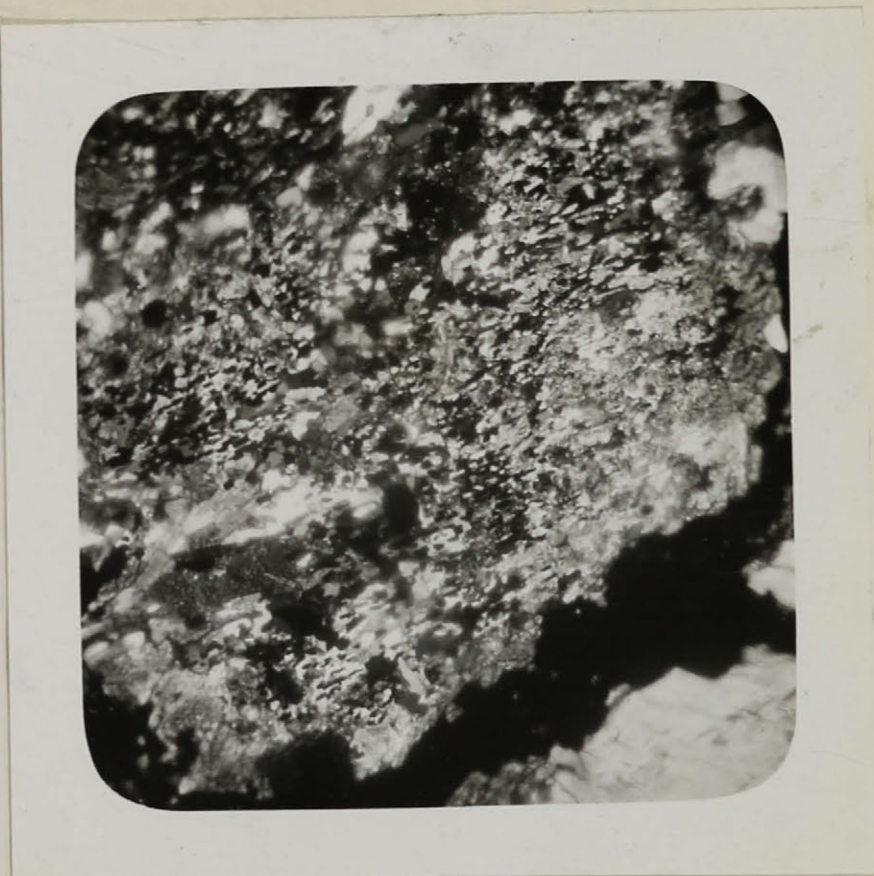


Fig. 6. Pyroxene altered to iron ore, quartz, biotite, etc.,

Fig. 7. Same as in Fig 6, with nicols crossed 12.

The principal mafic mineral is an amphibole

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* Alling, H.L., The Mineralography of the Feldspars, Jour. Geol. Vol. 29, 1921.

with optical properties dissimilar in one or two essential aspects to either common hornblende or uralite. These properties are: $Z \wedge c$ - $26\frac{1}{2}°$, optic axial angle - $45°$ to $50°$, dispersion weak with rho less than upsilon; pleochroism and formula- Z- grass green with brownish tinge, greater than Y - green with a hint of blue, greater than X- yellow. One of the grains observed contains a speck of zircon surrounded by a brown pleochroic halo.

In some sections a secondary origin for all the biotite is questionable. However, an examination of the most highly altered rock shows that, whereas the amphibole has altered to chlorite, calcite, etc., the biotite has remained in an unaltered state. Biotite is commonly one of the first minerals to be altered, and if the biotite were primary, it would have altered to chlorite at the same time as, if not earlier than, the other mafic minerals. Thus it is concluded the biotite is secondary and as such was not subjected to the reactions which have caused the chloritization of the primary minerals.

Apatite is an ever present mineral and commonly shows characteristic crystal outline. A large proportion of the magnetite may be secondary after pyroxene.

<u>The quartz-syenite (later series).</u> Megascopically this rock appears to be composed of pink feldspar speckled by small 1 mm. grains of diorite minerals.

Under the microscope it is holocrystalline, has an hypidiomorphic texture and an even granularity. It is composed essentially of:

plagioclase	---------	50 percent (Ab85 An15)
microcline	---------	20 percent
amphibole	----------	15 percent
quartz	----------	5 to 10 percent

Biotite is present but is probably secondary. The accessory minerals are magnetite, apatite and sphene.

Microcline and oligoclase occur as irregular grains up to 3 mm. in diameter, and both the faldspars are characteristically twinned; the peculiar intergrowth seen in the coarse-grained facies is present, but rare. Commonly, however, very short, parallel laths of plagioclase are microperthitically intergrown with microcline.

Quartz is present as irregular up to 2 mm. in diameter, but does not exceed 10 percent; hence the rock is classified as a quartz-syenite.

Idiomorphic crystals of amphibole are absent, but some of the fragments have a perfect prismatic cleavage. The optical properties of this amphibole are as follows: $Z \wedge c = 24\frac{1}{2}^{\circ}$; 2V small (about 25°); optically negative; dispersion strong with rho grater than upsilon. Pleochroism: Z - grass-olive green, greater than Y-blue green, greater than X-clear yellow. The absorption is not as great as in the hastingsite of the Althorpe granite but otherwise the two minerals appear to be essentially the same. The alteration to biotite does not follow a definite system; chloritization, on the other hand, is more common along fractures and cleavages than elsewhere.

Magnetite as clear-cut individuals up to 0.5 mm. in diameter forms about 5 percent of a rock section. Apatite is also a prominent accessory mineral, present as crystals and anhedra not exceeding 0.4.mm. in diameter.

GRANITE GNEISS ASSOCIATED WITH THE SYENITES.

A medium grained rock composed of pink feldspar, with quartz nodules and dull black amphibole and biotite, is found associated with the McCoy syenite on lot 27, concession 1, Crosby North township, Leeds county. The size of the grain averages about 4 mm. It is later than the syenite and may possibly be a facies of the Althorpe granite gneiss, from which it differs but slightly in appearance.

Microscopically the rock is holocrystalline, medium grained and has a cataclastic texture. Oligoclase, (Ab82 An18) forms 40 percent of a rock section, and in places is intergrown with potassic feldspar. At least a part of the feldapar is microcline as some of the grains are characteristically twinned, but the larger proportion of potassic feldspar grains are not twinned, and it is possible that microcline has formed from orthoclase as a result of rock deformation.

Quartz makes up 15 percent of the rock and amphibole another 10 percent. The accessory minerals are magnetite, sphene and apatite. (At least 3 percent of a rock section is apatite.)

Some grains show an antiperthitic intergrowth of microcline and oligoclase, the structure being similar to that present in the feldspars of the McCoy syenite (Fig. 5.) In places the intergrowth is reversed and microcline is the host of plagioclase lenticles.

The feldspars and quartz have been considerably shattered. The larger, irregular grains that are not granulated are contorted and commonly show strain shadows; they commonly appear as islands surrounded by aggregates of small quartz and feldspar-grains, and on their account the rock appears porphyritic.

In places, the oligoclase has altered to a mixture of calcite, sericite and chlorite. The secondary minerals are not in masses, but are in streaks across the feldspar, which commonly follow the cleavage lines. The orthoclase or microcline is fresh.

The amphibole is optically similar to that in the Althorpe granite. The extinction angle $Z \wedge c$ is 29°. 2V is less than 45° and probably as not great as 30°. The pleochroism is Z-olive green, greater than Y-blue green, greater than X-yellow. The very low birefringence and the elongation are negative.

The alteration product,- a golden yellow mineral-is probably the same as that previously described. Well-developed small crystals of apatite and magnetite are poikilitically included in the amphibole grains which are about 3 mm. long and 1 mm. wide, at a maximum, and which have a very ragged outline.

RELATIONS BETWEEN THE GRANITE GNEISS AT ALTHORPE AND THE McCOY SYENITE.

Summarizing, the granite gneiss at Althorpe contains in order of abundance, albite-oligoclase (Ab 90 An10), microcline, quartz and an amphibole near hastingsite, and in some sections a trace of diopside pyroxene. The accessory minerals are apatite, magnetite or ilmenite and sphene . The alteration products include a golden-yellow coloured mineral (in thin section) after amphibole. The feldspars show, rarely, microperthitic intergrowth. The McCoy syenite is composed essentially of 50 percent oligoclase (Ab82 An18), 15 percent microcline or orthoclase, 20 percent amphibole that is near hastingsite, and 10 percent diopsidic pyroxene. The feldspars always show an antiperthitic texture. The alteration product of the amphibole is similar to that of the granite gneiss at Althorpe.

It would be difficult to decide that the syenite and granite are from the same magma, using the data outlined. A consideration of the granite gneiss and the quartz-syenite , that are associated with the McCoy syenite, is essential, for they are the main factor in the correlation of the syenite and the Althorpe granite-gneiss.

The mineralogical compositions of the quartz-syenite and the granite gneiss associated with the McCoy syenite are very similar. The principal difference is the amount of quartz and feldspars. Both rocks are later than the McCoy syenite and it appears as though the quartz-syenite dykes are merely "off-shoots" or apophyses of the granite gneiss. These rocks contain in order of abundance:- oligoclase (Ab 82 An 18), microcline or orthoclase, an amphibole near hastingsite, and quartz. The accessory minerals and the alteration products of the amphibole are similar to those in the Althorpe granite gneiss and the McCoy syenite. The feldspars have an anti-perthitic texture which is characteristic of the McCoy syenite, and also show a perthitic texture which may be found in the feldspars of the Althorpe district.

From a mineralogical standpoint, the amphiboles and the peculiar textures of the feldspars indicate best the relation between the three types of rock.

The optical properties of the amphibole in the Althorpe granite-gneiss, as determined in thin section, are:

Birefringence very low, $Z \wedge c = 23^\circ$ to 28° (Z-b); optically positive; 2V very small; dispersion strong or medium, with rho greater than upsilon; pleochroism:X- pale yellow, Z- blue green, Y- olive green.

According to the data given by Winchell, this amphibole would belong in the hastingsite group.

The amphibole in the granite gneiss associated with the McCoy syenite has similar properties except that the optic axial angle (2V) may be as great as 30° . Dr. Adams, who defined hastingsite insists that the distinguishing optical property is the small optic axial angle, and Winchell limits 2V to 12° ; but Billings[x] has described members of the hastingsite group that have optic axial angles of at least 60°. Following Billing's classification, both these amphiboles would appear in the sub-division "Ferrohastingsite".

It cannot be determined with certainty to what group the amphibole in the McCoy syenite belongs ; the optical data suggest that it also belongs to the class "Ferrohastingsite". As pointed out by Billings, however, a group of alkali-rich amphiboles are found which may have optical properties essentially identical to those of hastingsite despite the fact that some of the oxides differ by 4 percent."

The texture of the feldspars is mostly antiperthitic in the McCoy syenite, and in the associated granite gneiss. The host is oligoclase and the clots, microcline

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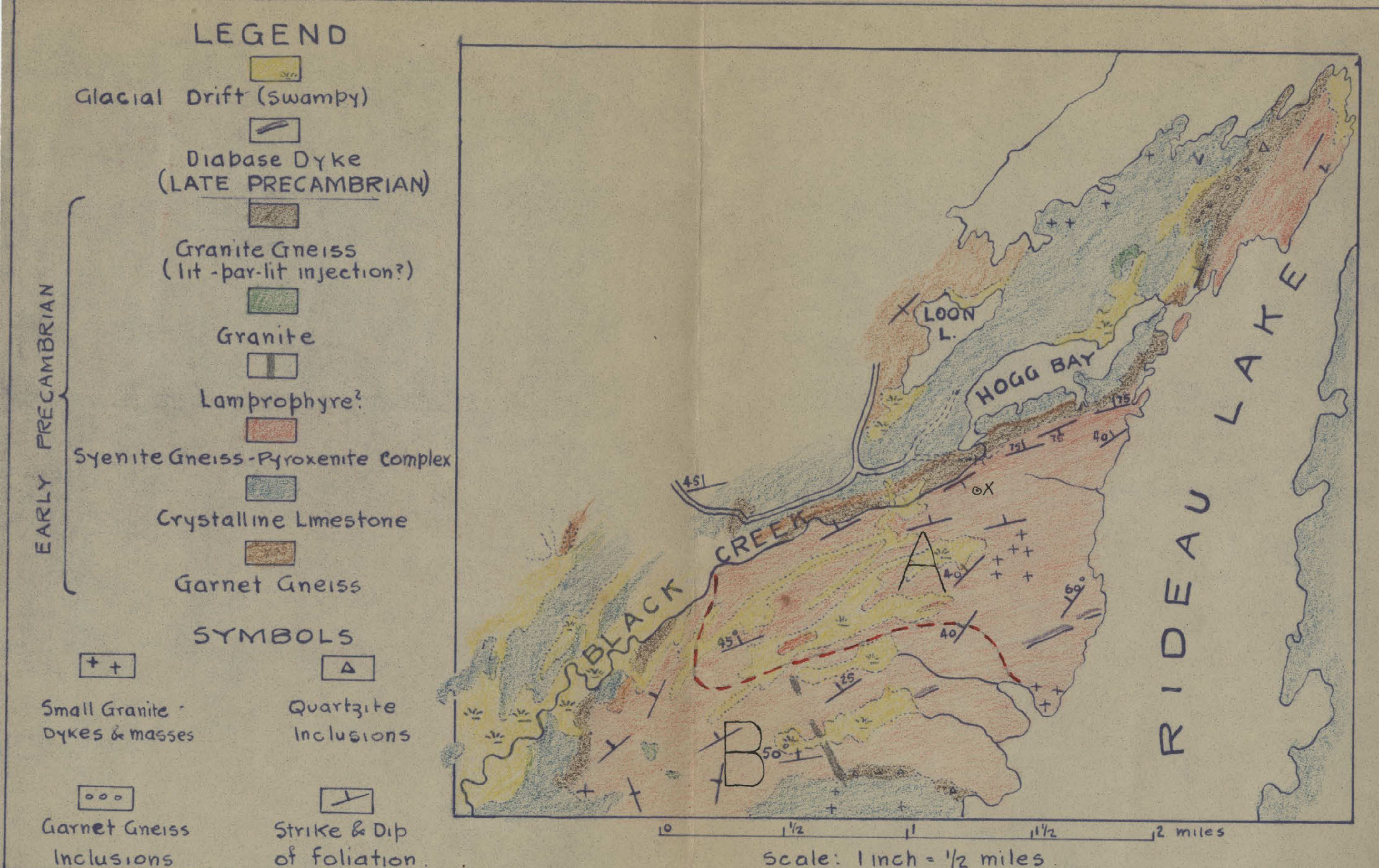
[x] Billings, Marland The Chemistry, Optics and Genesis of the Hastingsite Group of Amphiboles. Amer. Mineralogist Vol.,13, PP. 287-296.

(Fig.5). Perthite is present, but rare, in the Althorpe granite-gneiss and in the granite gneiss occurring with the syenite. In it, microcline or orthoclase is the host of oligoclase lenticles.

According to Alling,[x] perthitic and anti-perthitic textures may be due to an unmixing or "exsolution " of a supersaturated solution. If this be the case here, it is a phenomenon common to all the rocks.

In conclusion, the granite gneiss associated with the syenite has peculiar characteristics that are in part present in both the Althorpe granite gneiss and the McCoy syenite, which indicates that the three rocks are facies of the same magma.



DISTRIBUTION OF ROCKS IN THE VICINITY OF BLACK CREEK
BURGESS NORTH TOWNSHIP

FIG. 3.

Part C. THE ROCKS SOUTH OF BLACK CREEK

The rocks described below are from an area bordering Rideau Lake in North Burgess township. The facies of pyroxene syenite gneiss that are to be described in detail, however, are only found south of Black Creek.

The map in figure 3 shows the general distribution of rocks in the district. Pyroxene syenite gneisses occupy a wedge-shaped area bounded for the greater part by a lit-par-lit injection gneiss composed of Grenville quartzite garnet gneiss bands alternating with bands of granite gneiss. In places the syenite gneiss is in contact with crystalline limestone of Grenville age. Granite dykes, grading from aplites to fine-grained pegmatites, cut the pyroxene gneisses, and in one locality a granite mass roughly 300 feet in diameter intrudes the syenite. The diabase dike shown on the map cuts across the granitic intrusives and is the youngest Precambrian rock in the district.

THE PYROXENE-SYENITE COMPLEX

In the complex, very mafic gneisses composed of pyroxene, biotite and subordinate feldspar, grade into either pyroxenite or acidic pyroxene-syenite which have a gneissic structure that is apparent only in the field. The three facies are dommonly coarse-grained. In places they are injected by a fine-grained pyroxene syenite gneiss.

The coarse-grained rocks and the fine-grained syenite commonly occur as alternating wide bands which parallel the foliation. Later dykes and small irregularly-bounded masses of granite intrude the gneisses and pyroxenites. The dykes commonly have a very low dip, but they seldom lie in the plane of foliation. Only one or two outcrops of pyroxenite were observed. That examined in thin section occurs at X, figure 3. North and east of the broken red-line, in the area marked A, coarse-grained pyroxene-syenite gneiss preponderates, but is intimately associated with highly biotitic pyroxenic gneiss. South and west of the red-line(B), the fine-grained later facies of syenite is more abundant than coarse-grained rock, and highly mafic rocks are rare. In area A, the strike and dip of foliation tends to parallel that of the surrounding Grenville rocks, but in area B tend to parallel the periphyry of the intrusive complex. The dykes are concentrated mostly in area A, as shown by the crosses; nevertheless there is a mass of granite exposed in area B.

PETROGRAPHY.

Pyroxenite. Megascopically the rock appears to be composed almost entirely of a deep green to black pyroxene. The grains are equidimensional and average about 4 mm. in diameter. They show a good cleavage or parting in 3 directions not at right angles. The platy "diallage" parting is absent.

The microscope shows that pyroxene is the only primary mineral, and forms 85 percent of a rock section.

Amphibole (10 percent), calcium carbonate (5 percent), a trace of biotite, and chlorite are present, but all are probably derived from pyroxene. (Section 2.8 .24)

The pyroxene shows good cleavage, but the individuals have an irregular outline. A vertical section near 010 shows well-developed parting at 67° to the 110 cleavage traces. This parting is taken as parallel to 001. The mineral is a pale grey-green and has an extinction angle $Z \wedge c$ of 39° . The optical axial angle is about 60°, and the sign is positive. The dispersion is very weak, and pleochroism is hardly discernible. The optic axial planes of adjacent grains are approximately parallel, as shown by the interference figures.

The most abundant alteration product is an amphibole with an extinction angle $Z \wedge c$ of 16° a 2V of at least 80°, and strong dispersion with rho greater than upsilon. The pleochroic formula is Z-grass green, Y-yellow green, X-very pale yellow. The amphibole appears to have developed along the cleavages, and in places has replaced the pyroxene for at least 1 mm. on each side of the cleavage cracks.

Chlorite occurs along the cleavages and also the fractures. The development of calcite, on the other hand, does not appear to have been confined to fissures.

The optical data show that the pyroxene belongs to the diopside-hedenbergite group.

Mafic Syenite Gneiss: (sections 2.11, M.7) :- In the hand specimen, this highly biotitic facies resembles para gneisses of the pyroxenite type. The rock consists of a mixture of dark green to black pyroxene, pink to red feldspar, and black biotite. Crystals of pyroxene 3 or 4 mm. in cross section occur in places; commonly , however, the pyroxene grains are anhedral. The feldspar individuals are small and show good cleavage faces. The biotite gives the rock a gneissic structure, for the plates are roughly parallel to the direction of foliation.

Fig. 8. Antiperthite. Oligoclase (light), intergrown with orthoclase lenticles.

Pyroxene makes up about 35 percent of the rock and has optical properties almost identical with that present in the pyroxenite, differing in colour and form only. It is slightly deeper green and possibly faintly pleochroic, but the colour change is very slight. The edges of the grains appear to be corroded at the contact with feldspar.

The feldspars have a well-developed anti-perthitic texture (see Fig. 8). Oligoclase (Ab77 An23), is intergrown with lenticles of orthoclase and possibly microcline. The lenticles of orthoclase do not show a uniform orientation and may parallel the oligoclase cleavage, in which case each lenticle is straight and has a definite outline, or they may be transverse to the cleavage, and then the lenticles are ill-defined and irregular.

Each grain of feldspar averages about 60 percent oligoclase (host) and 40 percent orthoclase or microcline. Together, the two feldspars form approximately 25 percent of the rock. Secondary minerals after the feldspars are absent.

Seen in thin section, the biotite is greenish-brown to almost colourless. In places, the anhedral tablets have been corroded, and the space filled by oligoclase. The orthoclase lenticles die out as they approach the biotite. The reaction theory* accounts for the presence of biotite as an abundant constituent of the rock.

Mafic pyroxene-syenite poor in biotite:- The highly biotitic gneiss grades into rock consisting of deep-red feldspar bands about $\frac{1}{4}$" wide, which alternate with bands composed of dull green irregular grains of pyroxene and black biotite plates. The bands are not sharply defined: grains of pyroxene occur in the feldspar aggregates and vice versa.

Thin section No. 2.2.8 shows that the rock is composed of essentially 35 percent biotite, 40

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* Bowen N.L., Reaction Principle in Petrogenesis; Jour. Geol., Vol. 30, 1922.

percent pyroxene (diopsidic) and 7 percent biotite. Accessory minerals, apatite, magnetite and sphene total about 4 percent. The alteration products are chlorite and probably some biotite.

The feldspars are similar to those described above and show the same characteristic texture. Each grain of feldspar averages about 70 percent oligoclase and 30 percent orthoclase or microcline.

The intergrowth occurs as grains up to 7 mm. in diameter, commonly showing good cleavage. The shape of the grains is irregular and granulation at the edges of the individuals indicates deformation after solidification, Strain shadows are prominent and appear to be most common at the contact with pyroxene grains.

The oligoclase has been slightly altered to sericite and possibly calcite. The secondary minerals most commonly occur along the cleavage cracks. On the other hand, the potassic feldspars show no alteration.

The pyroxene is in grains up to 6 or 7 mm. in diameter. The individuals show good cleavage but a remarkably ragged outline. This irregularity may be due in part to cataclasis, but it is apparent that crystals have been corroded. In places, irregular grains of oligoclase appear to be poikilitically included in the pyroxene. However, the texture is not poikilitic; the feldspar has crystallized in hollows on the surface of corroded pyroxene grains. Magnetite and sphene are actually included in the pyroxene as small irregular grains. Alteration products are chlorite and some biotite. The chlorite is pale green and is confined to the cleavage and parting cracks.

Acidic pyroxene syenite- gneiss: This rock is coarse-grained and contains the same minerals as the mafic syenite gneiss. The proportion of minerals and the structure are different however, This rock shows no banding of the feldspars and mafic minerals, and the gneissic structure is evident only in the field.

Microscopic Examination: Section 2.13.2

Minerals	%	Distinguishing Optical Properties.
plagioclase		Ind. for beta greater than that for Can.
(oligoclase) (Ab77 An23)	55-60	Bal., opt. negative, 2V- 80 , 010-8½
orthoclase		Ind. lower than that for Can. Bal., biax. and neg.
pyroxene	30	Pale green, good cleavage, 2V about 55 or 60 Z c - 43 , positive elong. and bir. Faintly pleoch,

Accessory minerals

Apatite, sphene and magnetite, totalling 5 percent.

The oligoclase is antiperthitically intergrown with orthoclase in the Ratio Pl : Or :: 4: 1. The texture is somewhat different from that shown in figure 8, resembling rather that seen in the McCoy syenites (see Fig. 5).

The individual grains average 5 or 6 mm. in diameter and show good cleavage. The outlines are ragged and adjacent feldspar grains show an irregular boundary without a granulated rim. In places sericite, calcite and epidote have developed after the oligoclase. Needle-like crystals with a low birefringence and fairly high indices are scattered abundantly through the feldspar. These inclusions are minute and could not be determined with certainty.

The edges of the pyroxene grains are on the whole very ragged, and in places show a curving outline. The grains are deeply indented and the bays are filled with aggregates of small feldspar individuals. The alteration products are aggregates of chlorite, epidote and calcite, amphibole, and individuals of fibrous brown biotite. The optical data indicate that the pyroxene is a member of the diopside-hedenbergite series, and that it is very similar to that present in the associated pyroxenite.

The accessory mineral individuals are small and anhedral.

<u>The fine-grained syenite gneiss.</u> The fine-grained syenite gneiss is later than the rocks of the complex previously

described. Macroscopically, it appears to consist of pale-pink feldspar, grass green to dark green pyroxene or amphibole, and black biotite. The gneissic structure is due to paper-thin bands of biotite alternating with zones containing feldspar and pyroxene grains which are strung out in the direction of foliation. The distance between the biotite bands ranges from one-quarter of an inch to a foot. The rock breaks with an even fracture along the biotite bands; elsewhere the fracture is uneven.

The rock is composed essentially of :-

microperthite ------	45 percent
amphibole --------	25 to 30 percent
pyroxene --------	10 percent
biotite --------	10 percent

Traces of apatite, magnetite and zircon complete the primary composition.

The preponderating feldspar is orthoclase. This is intergrown with well-developed lenticles of oligoclase, Ab82 An18, as shown in Fig. 9. In general the texture is very similar to that of the antiperthite (Fig. 8), the difference being that the feldspars are here reversed.

The ratio of orthoclase to oligoclase is about 3 to 2. The intergrowths (treated as a mineral) are present as anhedra that do not exceed 3 mm. in diameter and commonly have ragged edges. They fill the indentations in the mafic minerals, and evidently a feldspar rich in the orthoclase molecule was the last mineral to cease crystallizing. The feldspars are commonly quite fresh. Rarely, sericite and possibly epidote and kaolin have developed as secondary minerals after both feldspars.

Fig. 9. Microperthite, orthoclase (grey) intergrown with lenticles of oligoclase. (white).

The amphibole and pyroxene have the following optical properties:-

Mineral	Optical Properties.
amphibole	Good prismatic cleavage; $Z_{\wedge}c = 14^{\circ}$; 2V about 80°; dispersion strong with rho less than upsilon; optically negative and positive elongation. Pleochroism

Mineral	Optical Properties
	and formula Y, green$>$Z, green$>$X, pale yellow.
pyroxene (diopsidic)	Colourless, but somewhat clouded due to inclusions of magnetite and secondary mineral. Perfect prismatic cleavage and possibly a diallage parting, $Z \wedge c$ approx. $=39^\circ$, 2V about 60°. Birefringence positive, rho greater than upsilon and dispersion stronger for axis A than axis B. Alteration products; amphibole, biotite and calcite.

The grain-size of both these minerals ranges from minute to 2.5 mm. Corrosive action has evidently been intense and the indentations in the grains have been filled with feldspar.

The biotite is strongly pleochroic; the formula being Y and Z rich brown and X almost colourless. The individuals are anhedra that show slight corrosion, Pleochroic haloes around minute grains of zircon were observed in one or two grains of the mineral. The greater part of the biotite was probably primary.

Magnetite and apatite occur as anhedra scattered through the rock, but the grains are most abundant close to the mafic minerals. The magnetite is altered in places to hematite.

Granite dykes and sills: Megascopically, the granite dykes and sills cutting the gneissic rocks are phanerocrystalline and composed of flesh coloured feldspar, quartz and subordinate dark minerals. Excepting a few well-developed crystals of feldspar up to one cm. in diameter, the minerals appear to be anhedra. The granularity is commonly fine and the fabric uneven.

A thin section of dyke-rock cutting the fine-grained gneiss shows that the rock constituents in order of abundance are: quartz, microperthite, pyroxene, magnetite, sphene and apatite.

The microperthite is composed of oligoclase lenticles in an orthoclase matrix, the ratio being Or : Pl : 3 : 2, and on the whole the feldspars are very similar in appearance to those of the fine-grained (later) gneiss described above.

The quartz, which forms one-half of the rock, commonly occurs as anhedra, but in places it shows crystal outline. Micrographic intergrowths of quartz and microcline with a vermicular texture are present, but rare.

Pyroxene, forming 5 percent of a rock section, occurs in grains not exceeding 0.5 mm. It has the following optical properties:

Bright green to greenish-yellow. 2V about 60°, optically positive. Maximum extinct. angle obtainable-34°. Rho is less than upsilon. Some grains show schiller structure and good cleavages at 90°.

Lit-par-lit injection gneiss: The rock bordering the syenite gneiss complex is a banded, ridged-weathering gneiss, that is predominently a blue quartz granite interbanded with a brown-weathering, fine-grained rock that looks like garnet gneiss but contains no garnets. The strike and dip is parallel to the syenitic rocks.

Under the microscope the granite shows:

quartz	45%	some grains contain hair-like inclusions of an undeterminable mineral and small brown grains of rutile. A little micrographic intergrowth.
feldspar	53%	Microcline, microperthitically intergrown with spindles of plagioclase with a positive sign. There has been some secondary formation of albite, quartz and sericite after microcline.
biotite	trace	Greenish-brown to pale brown. Quasi-uniaxial and negative.
magnetite	trace	

All the minerals are anhedra, and show some granulation.

This rock is apparently a very late facies. It is a leucocratic rock that may be called an alaskite.

THE ORIGIN AND CORRELATION OF THE SYENITE ROCKS.

Before attempting to show the age relationships of the syenitic rocks it is necessary to consider their origin. Two principal possibilities are open;(a) the syenite and pyroxenites may be differentiates of a common pyroxene-syenite magma; (b) the large amount of limestone present in the Grenville series may have, in some fashion, influenced a granitic or syenitic magma to change its composition either by mechanical or chemical incorporation of limestone or contact-metamorphic products of carbonaceous rocks, and thus give rise to the different facies of the complex.

Considering the first possibility;- if the magma producing the pyroxene syenites and the pyroxenites were intruded in a period of stress, filter-pressing out of interstitial liquid following the crystallization of the early minerals might give rise to a concentration of pyroxene which now could be called a pyroxenite. Certain features, however, suggest that the pyroxenite did not originate by filter-pressing from the syenite magma. Osborne[x] has shown the possibilities of the mode of origin of certain magmatic iron ores and shows that the separation is almost invariably accompanied by a marked deformation of the original web of crystals to allow the rest-magma to be drained out.

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[x] Osborne F.F., Certain Magmatic Titaniferous Iron Ores and their Origin; Econ. Geol., Vol. 23, 1928 pp. 896-904.

Such a structure is absent in the pyroxenite. No evidence of pyroxene grains being broken and the fractures healed by rest-magma precipitation could be noted. Furthermore the pyroxenite would be in the position of "schileren" parallel to the direction of the movement and the outcrop map shows that in part the structure is influenced by the direction of trend of the older formations and in part by the direction of the molar contact of the igneous intrusions.
(b) :- The influence of the Grenville limestone or metamorphic products derived from it on the magma is the most probable origin for the complex. Diopside is a very common product of metamorphism of the Grenville limestones and it is possible that masses of the Grenville were altered to metamorphic pyroxenite preceding the intrusion of the syenite magma. The metamorphic pyroxenite would tend to be massive without much directional structure if we except a slight tendency of banding parallel to the bedding. When this was intruded by the syenite magma, parts of it were torn off and incorporated by "crustal stoping" and parts were merely held by the magma. Some of these rest-blocks retained the direction of the old bedding structure.

The new pyroxene reacted with the magma to form amphibole and biotite in precisely the same way as it would if the pyroxene werecan early phase that had been precipitated from magma. In thin sections, the incorporated crystals show corroded outlines, but it is impossible to determine whether they originated in this way. However, the field evidence appears to support this hypothesis, It is even possible that instead of an advance wave, the syenite magma caused the contact-metamorphism of the limestone itself by incorporating blocks and fragments, making them over into pyroxenite, and forming the highly mafic gneisses as it advanced. However, the syenite gneiss is free from carbonate and if this hypothesis were true, traces of carbonate might be expected to remain.

Regardless of origin, the syenite gneiss complex is closely related in age to the granite batholith. Microscopic examination shows that the igneous rocks of the complex from the acidic syenite gneiss to the alaskite have common characteristics, the most important being the feldspar textures, which would indicate that they are from the same magma. However the dubious origin of the complex renders data from petrographic observation and chemical analysis inadequate to correlate the syenite gneisses and later rocks of the complex with the McCoy syenite and the granite gneisses at Althorpe. The correlation must be based on field evidence and the field data collected to date would indicate that the igneous rocks of the complex, the McCoy syenite and the granite gneisses are probably derivatives of a common magma, which in the case of the pyroxene-syenites injected and broke off fragments of metamorphic pyroxenite with possibly some desilication.