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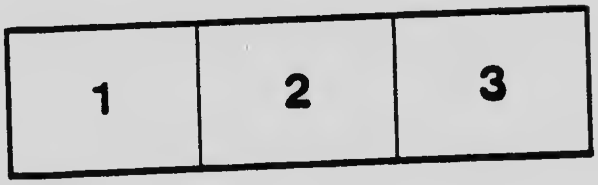
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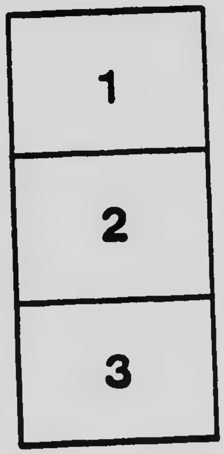
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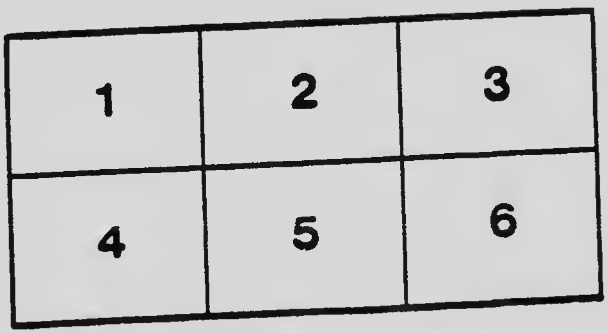
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CANADA

DEPARTMENT OF MINES

HON. LOUIS CODERRE, MINISTER; A. P. LOW, DEPUTY MINISTER

GEOLOGICAL SURVEY

R. W. BROCK, DIRECTOR.

MEMOIR 43

No. 36, GEOLOGICAL SERIES

St. Hilaire (Beloeil) and Rougemont Mountains, Quebec

BY

J. J. O'Neill

OTTAWA
GOVERNMENT PRINTING BUREAU
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CHAPTER I.

THE MONTEREGIAN HILLS

INTRODUCTION.

From Mount Royal at Montreal, a series of eight, isolated hills stands out conspicuously upon the surrounding plain of the St. Lawrence lowlands and extends, with general trend a little south of east, across the Province of Quebec. Six of these hills are spaced at intervals of about 10 miles and occur in the following order from west to east: Mount Royal, Monterville or St. Bruno, St. Hilaire (Beloeil), Rougemont, Yamaska, and Shefford. Nine miles southeast of Rougemont is Mount Johnson, and Brome is situated 2½ miles south of Shefford. These eight hills form the petrographical province named by Dr. F. D. Adams,[1] the Monteregian Hills.

The investigation, of which this report is the result, was carried on during the summer of 1912 with the object of studying St. Hilaire (Beloeil) and Rougemont mountains and thus completing the detailed study of the petrographical province of the Monteregian Hills. A topographic map recently issued by the Department of Militia and Defence was used as a base for the geology, and field work was carried on alone, except for temporary assistance in surveying contacts, and in blasting to obtain fresh material. The pace and compass method of surveying was used in locating individual points and this was checked by aneroid determinations; a telemeter was used in surveying contacts.

The author is greatly indebted to Professor L. V. Pirsson for assistance and criticism in preparing the petrographical section of this report, and to Professor Charles Schuchert for help in working out the stratigraphy; his thanks are also due to Professor Isiah Bowman for criticism of the physiography, and to Professor Joseph Barrell for suggestions bearing on structural geology.

[1] The Monteregian Hills: A Canadian Petrographical Province Jour. Geol., Vol. XI, No. 4, April-May, 1903.

The St. Lawrence lowlands in the Province of Quebec lie between the Appalachian mountains on the southeast, and the Laurentian plateau on the northwest. This intermediate lowland is the final product of Tertiary erosion upon soft strata of Palæozoic age. The western portion of the plain of the lowlands is developed on nearly horizontal strata and is separated from the eastern part by a thrust-fault known as the "St. Lawrence-Champlain" fault, or the "Logan" fault-line of Schuchert.[1] This represents an overthrust from the southeast and the strata to the east are standing on edge with steep dips to the southeast.

Across this lowland, in a line a little south of east, extends a series of ten isolated hills which rise abruptly from the plain and are spaced at more or less regular intervals, making a bridge from the Laurentian plateau to the Appalac' ian mountains. The two most westerly of this series are outliers of the Pre-Cambrian and are not related to the other eight; the latter are closely related both in age and in the high sodic content of the intrusive igneous rocks forming the central portions of the hills, so that they have been called "The Monteregian Hills," and form a distinct petrographic province as pointed out by Dr. F. D. Adams. From west to east these mountains are: Mount Royal, St. Bruno, Johnson, St. Hilaire (Beloeil), Rougemont, Yamaska, Shefford, and Brome. Some of these have been described as typical volcanic necks, and others as of laccolithic origin; the present paper gives a detailed description of St. Hilaire (Beloeil) and Rougemont, and a summary of the other occurrences is here given for reference and comparison.

MOUNT ROYAL.

Mount Royal is the most westerly of the Monteregians; it has an area of about 2 square miles and an absolute altitude of 769 feet. It is made up of three principal hills, connected by ridges which have been more or less worn down, enclosing a broad, relatively flat basin. The igneous mass of the mountain is the product of two main intrusions, the first one of essexite made up of "labradorite, reddish-violet augite, brown hornblende, and brown

[1] Paleogeography of North America. Bull. Geol. Soc. Am., Vol. XX, 1910, pp. 427-606.

mica", while olivine, titanite, apatite, and other accessories are often present; "nephelite is present only in very small amount and haüyne can be occasionally detected". The second intrusion occurred on the north side of the essexite body, where a mass of nephelite-syenite cuts the essexite and sends off arms into it; the contact is well exposed at the Corporation quarries. This rock is "composed essentially of orthoclase, nephelite, and green hornblende, with small quantities of plagioclase, pyroxene, garnet and nosean, and other accessory minerals"; Dr. Harrington has also found sodalite in it in some places.[1]

These main intrusions were followed by the formation of great masses of breccia in sheets and dykes intruded into the sediments surrounding the igneous core of the mountain, and by a complementary set of dykes of the bostonite-tinguaite-monchiquite series, cutting all the earlier rocks and one another. In the excavation for the Montreal reservoir on McTavish street, Dr. Harrington was able to determine five distinct sets of dykes, and to recognize their relative order of intrusion. There is also a dyke of alnoite[2] found at Ste. Anne de Bellevue, "which is probably also connected with the Mount Royal intrusion." The breccias of Mount Royal have been investigated by Robert Harvie,[3] who finds them to be of intrusive origin; they contain fragments of all the local formations from the Potsdam to the Oriskany, and are well exposed in many places, perhaps best on St. Helen island. The churning action which brought together in this breccia, fragments of rock of such widely different horizons (Oriskany to Potsdam) would suggest that the conduit of the magma extended right to the surface.

In referring to the origin of Mount Royal, Dr. Adams says,[4] "In a recent paper by Buchan (Can. Rec. Sci., Vol. VIII, 1901, p. 321) the view was put forward that Mount Royal represents the remnant of a denuded laccolite—on the ground that on one side of the mountain, towards the summit, there is an isolated mass of flat-lying, altered Palaeozoic limestone, evidently a part of the sedi-

[1] Drs. Harrington and Adams as recorded in the Ann. Rept., Geol. Surv. Can., Vol. VII, Pt. J, pp. 74-75.

[2] Adams, F. D. Dr., Am. Jour. Sci. 3rd Ser., Vol. XLIII, pp. 269-279.

[3] Proc. Roy. Soc. Can., 3rd Ser., Vol. III, Sec. 4, pp. 249-299, 1910.

[4] "The Monteregian Hills.—A Canadian Petrographical Province." Jour. of Geol., Vol. XI, No. 3, p. 253.

mentary strata of the plain from which the mountain rises. This alone, however, is not sufficient to establish a laccolitic origin, and opposed to such an explanation is the fact that where the strata of the plain are seen along the immediate contact with the intrusion in many places, especially on the eastern and northern side of the mountain, they abut against the intrusive rock and are cut off by it instead of being uptilted, the igneous core of the mountain rising up precipitously like a wall across the truncated edge of the beds."

It appears that the origin of this mountain is yet in doubt, and further work is necessary for its determination.

ST. BRUNO MOUNTAIN.

This mountain has been described by John A. Dresser[1] as probably a laccolith, but the evidence was not such as would warrant a definite decision. It has an area of 2·83 square miles above the 300-foot contour, with an igneous core of 2·16 square miles. The maximum elevation occurs in the northeast part of the mountain and is 715 feet absolute, or 620 feet above the surrounding plain. The surface is uneven, giving an imperfect drainage, and causing the formation of three small lakes which have beds of reworked glacial material, and a maximum depth of 17·5 feet. There was but one main intrusion, an essexite magma made up of abundant biotite, hornblende, and augite, with basic labradorite; olivine is occasionally present in considerable amount. This type seems to grade rather sharply into a rock termed umptekite, which occupies an area about 500 feet long and a little less in width; it consists of "orthoclase, plagioclase, microperthite, biotite, and a colourless augite. It has a granitic structure and a medium texture."

MOUNT JOHNSON.

This is the smallest of the Monteregian hills and is described by Dr. F. D. Adams[2] as a typical volcanic neck or pipe. It is situated about 9 miles, a little west of south, from Rougemont

[1] Geology of St. Bruno Mountain (Quebec): Can. Geol. Surv., Memoir No. 7, 1910.

[2] The Monteregian Hills: A Canadian Petrographical Province. Jour. Geol., Vol. II, 1903, pp. 239-282.

mountain; its area within the outer edge of the hornstone collar is approximately 0·77 square miles, and the area of the igneous core is 0·423 square miles. The mountain rises to an absolute elevation of 875 feet or about 720 feet above the plain; it is nearly circular in outline. There has been only one main intrusion in this case, and it shows an exceptionally perfect differentiation with more or less abrupt transition from pulaskite on the borders to an essexite core. The pulaskite, or soda-syenite, is made up of "biotite, hornblende (pyroxene), soda-orthoclase, nephelite, sodalite, apatite, magnetite, and sphene." It has a decidedly porphyritic, but massive structure, and has a marked preponderance of feldspar. The essexite contains the same minerals as the pulaskite, except that there is very little orthoclase present, and the plagioclase varies from an acid labradorite to oligoclase though most of it is andesine; olivine is also present in small amount. The central portion is finer grained and is massive. Flow structure is well displayed in the essexite but more particularly in the transition zone to the pulaskite, where the large phenocrysts of feldspar are prominent. The banding follows the border contact, in strike, and in dip it is nearly vertical, showing an upward movement of the magma.

CHAMBLY OCCURRENCE.

"At Chambly a mass of porphyritic trachyte is in the form of a bed among the strata of the Hudson River formation (Richmond); and about midway on the Chambly canal, a similar trachyte is met with which contains in drusy cavities, crystals of quartz, calcite, analcine, and chabazite. The base of this rock is of a pale fawn colour, and appears at first sight to be micaceous, but on closer examination it is seen to be almost entirely feldspathic; minute portions of pyrites and grains of magnetite iron are rarely met with, and small scales of a dark green, micaceous mineral are very abundant; they are sometimes an inch in length and one-fourth of an inch in thickness."[1]

MOUNT YAMASKA.

This mountain is situated about one-half mile east of the St. Lawrence and Champlain fault line, and it has been said to be on the line of an inferred fault, parallel to the former, and forming the

[1] Geol. of Canada, Logan, 1863, p. 657.

contact between two members of the Quebec group; the Sillery
the east is older than the Farnham on the west. It has been th
oughly studied by G. A. Young, who is inclined to believe that
mountain is situated on the axis of an overturned anticline and
on a fault.[1] Yamaska is elliptical in outline with the long
running northwest and southeast, and is bounded by two main ou
ridges running lengthwise. The general elevation of these rid
is about 1400 feet, and the highest peak is 1470 feet above the s
The divide in the interior basin is 950 feet above sea-level.

The sedimentary collar is widest on the north and south fa
where it reaches nearly to the summit; on the east and west fac
the contact is near the base of the mountain. The igneous
has an area of 3·1 square miles, and is very irregular in outli
It includes three main types of rock—akerite, essexite, and yam
kite, with abrupt transitions, although there has been but
main intrusion. Owing to lack of exposures the complete relati
ships could not be established. The akerite is a medium
coarse-grained, light grey rock, in which labradorite and al
feldspar greatly predominate over the diopside, biotite, and mi
constituents among which there is a small amount of qua
The akerite appears to be a border facies. Essexite is presen
three varieties, divided on the basis of textural differences,
grades into the most highly ferromagnesian rock type pres
which has been called yamaskite. This rock is characterized
the great preponderance of pyroxene, basaltic hornblende,
ilmenite, with about 2 per cent of anorthite (at 15 per cent
feldspar, the rock passes into essexite). The dyke rocks incl
bostonite, camptonite, syenite-aplite, nephelite-syenite, and yam
kite, and are relatively abundant close to the margins of the m
intrusive. The total weight of evidence points to the conclus
that this mountain is the remains of a volcanic neck.

SHEFFORD MOUNTAIN.

John A. Dresser[2] describes Shefford mountain as a laccoli
intrusion, having an area of less than 8 square miles, and
maximum altitude of from 1,500 to 1,700 feet above the s

[1] Geology and Petrography of Mount Yamaska: Ann. Rept., G
Surv. Can., Vol. XVI, Pt. H, 1905, p. 31.

[2] Report on the Geology and Petrography of Shefford Moun
Quebec): Ann. Rept., Can. Geol. Surv., Vol. XIII, 1902, Pt. L.

It is the product of three separate intrusions; first, a normal essexite, without olivine, was intruded and this was followed by a nordmarkite magma composed principally of coarsely crystalline microperthite (albite-orthoclase) with a small amount of ferromagnesian minerals, mostly augite. Lastly, a body of pulaskite was thrust in between the essexite and the nordmarkite. It differs from the nordmarkite in having a porphyritic structure and in having hornblende instead of augite as the characteristic bisilicate. Each of these three intrusions was accompanied by a set of dykes. The same foliated structure as described at Brome is here also in evidence.

BROME MOUNTAIN.

Brome mountain is a laccolith with an area of 30 square miles, and it is the largest of the Monteregians. It is rudely circular in form and the central portion is a nearly level basin 2 miles wide by 2·5 miles in extent, with an absolute altitude of 500 feet, or 50 feet above the country level. Surrounding this basin is a nearly continuous rim of hills which rise 600 to 1,000 feet higher; the highest point on the mountain is thus 1,500 feet above the sea. In this case there were three igneous intrusions: the first was an essexite magma with about 90 per cent of plagioclase, varying from labradorite to bytownite, with a little nephelite; the second was composed of nordmarkite, which also contains about 90 per cent of feldspar, a kryptoperthic intergrowth of albite and orthoclase; the third intrusion was the smallest and proved to be a tinguaite, "a porphyritic rock having a green matrix and a few phenocrysts of light grey colour"; it contains nephelite, orthoclase, sodalite, and aegerite. There were relatively few dykes following these invasions.

The rocks exhibit a foliated and incipient schistose structure parallel in direction with the foliation of the surrounding sediments, and this is thought to have formed during a late stage in the folding of the Appalachians. This mountain is only 2·5 miles south of Shefford and from the similarity in the order and composition of the intrusions, Dresser[1] concludes that on the whole "it

[1] Summary from Report on the Geology of Brome Mountain, Quebec. Dresser, J. A., Can. Geol. Surv., Ann. Rept., Vol. XVI, Part G, 1906.

seems probable that Brome and Shefford are merely parts of great laccolith and that the connecting part is only lightly cov by Palaeozoic sediments."

EASTMAN.

A Monteregian in miniature was recognized by Mr. Joh Dresser during field work on the Serpentine Belt in the summ 1910. This occurrence is only 200 feet in diameter, but it is tinct, and represents the most easterly known member of the gr It is exposed in a cutting on the Canadian Pacific railway a 1½ miles east of the village of Eastman, Que., and its dist from Mt. Shefford, the nearest of the larger hills, is about 15 m The rock types of this locality have not yet been studied, Dresser has stated that a dyke, presumably from this occurre is found cutting the serpentine a short distance away, provi to be younger than the great peridotite-pyroxenite intrusio the east.

Tabulated Summary.

Mountain.	Area in sq. miles.	Maximum absolute elevation.	Maximum elevation above plain.	Nature of intrusion.	No m intru
Brome.....	30·0	1,500	1,100	Laccolith..	[illegible]
Shefford.....	9·0	1,500	1,300	Laccolith	[illegible]
Yamaska.....	5·5	1,500	1,300	Neck......	
Rougemont...	* 9·5	1,260	1,140	Neck	
Johnson......	† 0·771	876	720	Neck......	
St. Hilaire...	* 6·76	1,375	1,230	Neck	[illegible]
St. Bruno....	‡ 2·83	715	620	..?........	
Mount Royal.	2·0	769	650	Neck?......	[illegible]

* Above the 200-foot contour. † Above the 300-foot conto
‡ Above a contour of 190 feet above the plain.

Mountains in order from east to west.	Main intrusions in each in order of occurrence.			Nature of intrusion.	Investigator.
	No. 1	No. 2.	No. 3.		
Shefford....	Essexite....	Nordmarkite	Palaskite	Laccolith.	Dresser.
Brome	Essexite to theralite.	Nordmarkite to nephelite syenite and dykes.	Tinguaite..	Laccolith.	Dresser.
Yamaska.....	Yamaskite to essexite to akerite.	....	....	Neck.....	Young.
Rougemont...	Yamaskite to essexite to rougemontite.	....	....	Neck.....	O'Neill.
Johnson......	Essexite to pulaskite.	....	....	Neck...	Adams.
St. Hilaire...	Essexite to rouvillite.	Nephelite-syenite.	....	Neck.....	O'Neill.
St. Bruno....	Essexite to syenite (umptekite)	....	....	Laccolith?	Dresser.
Mount Royal.	Essexite....	Nephelite syenite...	....	Neck?.. Laccolith?	Adams. Buchan.

CHAPTER II.

THE PALÆOZOIC STRATA IN THE NEIGHBOURHOOD OF ST. HILAIRE (BELOEIL) AND ROUGEMONT MOUNTAINS.

GENERAL ACCOUNT.

St. Hilaire (Beloeil) and Rougemont rise from the portion of t St. Lawrence lowlands underlain by gently dipping Palæoz strata which are here mainly Ordovician. The lowest member the series is of late Cambrian or lowest Ordovician age, and ov laps the Pre-Cambrian about 30 miles to the northwest; sout eastward higher divisions successively outcrop culminating the Richmond (Lorraine). The total thickness is estimated about 4,000 feet of apparently conformable strata, but there a doubtless some disconformities.

In the neighbourhood of St. Hilaire and Rougemont the stra consist of shale for the most part, with occasional thin interbedd limestone layers; the measures are comparatively undisturbed a are preserved as a hornstone mantle about the mountains to elevation of over 1,000 feet above the plain.

THE RICHMOND AGE OF THE SO-CALLED LORRAIN

The series of black shales conformably overlying the Ut shales in the Montreal district, varies in thickness reaching a ma mum of about 2,000 feet. It has been commonly classed as L raine, and there is said to be a gradual transition from Utica Lorraine. Collections of fossils have been made at various tim from this formation: at Chambly, St. Lambert, Riviere d Hurons, Rougemont, and St. Hilaire station. The fossils th secured, except in the case of those from St. Hilaire, have been d termined by Dr. Ami, and lists of them are published in the Annu Report of the Geological Survey of Canada, Volume VII, Part 1896. The collection from St. Hilaire station was described Dr. E. O. Ulrich, in Memoir No. 7, Geological Survey of Cana

"Geology of St. Bruno Mountain" by John A. Dresser. The strata at all of the places listed by Dr. Ami were placed in the Lorraine; it is now believed that there are no typical Lorraine fossils listed, and that the general character of the fauna, as well as the species, points to the Richmond.

Concerning the collection made by R. Harvie, from St. Hilaire, Quebec, Dr. Ulrich says: "The St. Hilaire fauna, as represented in the small collection before me, is not decisively Richmond, but so far as it goes, it indicates lower Richmond rather than Lorraine. The matter is so important that it seems worth while to recommend the making of a full collection. The most significant fossil in the lot is the fragment provisionally referred to *Whiteavesia pholadiformis*. So far as we know, this type of shell occurs only in Richmond faunas. Pointing in the same direction is the presence of two species of Whitella, a genus so far unknown in Lorraine faunas. This evidence is further corroborated by the *Palaeschare beani*, but the specimen is small and not in sufficiently good preservation to permit positive identification. The "Olidophorus" I have found in both Lorraine and lower Richmond likewise *Psiloconcha sinuata, Pholidops cincinnationsis* and *Ctenobolbina ciliata*. The remaining things being either new, or not definitely determinable, may be disregarded. I will say, however, that I see nothing about them that might be used in rebuttal of the general trend of testimony afforded by the species mentioned."

FOSSILS FROM ST. HILAIRE STATION.

On the strength of this determination, it was deemed advisable to make a full collection in connexion with the field work of the present report. The fossils thus secured have been examined by the writer, under supervision of Professor Charles Schuchert, and the following determinations arrived at:—

Bryozoa.

Stomatopora. Sp. undet. Rare.

Paloeschare beani (James). Nearly always growing over *Cyrtolites ornatus*.

Brachiopoda.

Pholidops subtruncata (Hall) or *Pholidops cincinnationsis* (Hall). Both forms appear to be present and may represent but one species. The individuals are not rare, and are larger than usual.

Rafinesquina alternata (Emmons). Very rare.

Zygospira modesta (Hall). Not common.

Pelecypoda.

Pterinea demissa (Conrad). Not common.

Byssonychia suberecta (Ulrich). A very common species in harmony with Ulrich's description and figures, but none attain the large size of the Ohio individuals.

Psiloconcha sinuata (Ulrich). Common.

Psiloconcha suboralis (Ulrich). Common.

Psiloconcha inornata (Ulrich). Common.

Modiolopsis concentrica (Hall and Whitfield). Rare.

Whiteavesia pholadiformis (Hall)? Fragmentary and very rare.

Whitella, species No. 1. Rare.

Whitella, species No. 2. Rare.

Whitella, species No. 3. Rare.

Rhytimya radiata (Ulrich). Common.

Cymatonota semistriata (Ulrich). Common.

Cymatonota recta (Ulrich). Rare.

Ctenodonta pectunculoides (Hall). Very common.

Ctenodonta, sp. undet. Of the *C. lerata* group.

Clidophorus n. sp., near *C. planulatus* (Conrad). Very common.

Gastropoda.

Cyrtolites ornatus (Conrad). Rare.

Tubiculus annelida.

Conchicolites richmondensis (Miller)? Smaller than is usual in this species.

Ostracoda.

Ctenobolbina ciliata (Emmons)? Common.

Trilobita.

Isotelus gigas (De Kay)? One large free cheek, with its genal spine.

In summing up this collection, Professor Schuchert makes the following statement:—

"Ulrich, in 1907, (see above quotation), pointed out that the St. Hilaire fauna is not decisively Richmond, but, so far as it goes, it indicates lower Richmond rather than Lorraine. While this fauna is now considerably enlarged, yet no marked addition has been made of decisive Richmond fossils. On the other hand most of the species have the time development of the Richmond, and the St. Hilaire fauna is for the present best referred to this time rather than to the Lorraine. The St. Hilaire fauna is derived entirely from shales and is, therefore, a mud-loving fauna, devoid almost entirely of brachiopods, bryozoa, and the other groups of invertebrates usually met with in calcareous deposits. In general the Richmondian faunas are derived from limestones and calcareous shales."

It is interesting to note that the fossils listed above were collected from nearly horizontal strata at an elevation of about 120 feet above sea-level, and that the same formation forms the hornstone collar of St. Hilaire mountain, which rises about one mile to the east, and it is found there at an elevation of over 1,000 feet above the sea; there is, therefore, a vertical exposure of about 900 feet with the top removed, so that the fauna is from the lower part of the formation, and not far above the Utica. No fossils were found in the hornstone near the mountain, although careful search was made at a number of points; where they do occur they are prolific, in thin bands separated by many times their thickness of apparently barren layers.

FOSSILS FROM NEAR CAROLINE STATION.

In 1872, Thomas Curry made a collection of fossils from just south of Rougemont mountain; these are included in Ami's lists and also were regarded as indicating Lorraine, but now are thought to be distinctly Richmond. The writer was unable to find this locality, but discovered fossils to the east of the mountain near the Petite Caroline road, about one-fourth of a mile south of Caroline station on the Quebec, Montreal, and Southern railway. At this place the strata dip to the west at a low angle and only the edges of the beds are exposed so that the collecting of fossils is not easily accomplished; the beds containing the fossils are easily recognized by the fact that the abundant crinoidal columnals have been dissolved out, leaving corrugated channels through the strata.

Professor Schuchert examined this collection and determined the following:—

Crinoidal columnals very abundant.
Dalmanella testudinaria (Dalman).
Plectambonites sericeus (Sowerby).
Catazyga anticostiensis (Billings)?
Cteidophorus, sp. undet.
Calymene callicephala (Green).
Trinucleus concentricus (Eaton).

In discussing this fauna he says: "The fossils from this horizon are meagre and poor so that one cannot be certain of their time values. *Catazyga anticostiensis* appears to have the most reliable time value, and on this evidence the horizon is early Richmond. The other fossils do not help out one way or the other, excepting that Trinucleus is not known to be above the Utica. In north-western Europe, however, the genus is abundantly represented at the very top of the Ordovician, and, therefore, I see no reason why Trinucleus should not turn up in these northern Richmond faunas. *Catazyga erratica* is abundant in the Lorraine, and is closely related to *C. anticostiensis*. As the present material is poor, it may be that my identification is not correct. In this event the horizon would seemingly be Lorraine or even the lower Frankfort. With this view the association of *Trinucleus concentricus* is harmonious in making the age of these fossils Lorraine or Utica rather than Richmondian."

It would seem, then, that this horizon may be lower than that from which Curry collected, which is only 2 miles distant, in a line nearly due west. The vertical distance between them is not very great.

CONCLUSIONS.

In looking over the lists of fossils collected at (1) Chambly, Que.; (2) St. Hyacinthe, Que.; (3) Yamaska river near St. Hyacinthe, Que.; (4) Rougemont, Que., (a) south of the mountain, (b) east of the mountain; and (5) the Riviere des Hurons, Que., it is seen that in cases (1) and (4a) the faunas contain *Catazyga headi* (Billings) which is typical of the Richmond, and that the latter fauna contains also *Leptaena nitens* (Billings), so that these two places, at least, are in the Richmond. The fossils from (3) include two characteristic Trenton fossils, *i.e. Dinorthis pectinella* (Conrad), and *Plectorthis plicatella* (Hall). The fossils from (2) and (4b) seem to resemble this group rather than the others; they have *Trinucleus concentricus* in common, which is not present, or at least has not been found, in the other occurrences. Geographically these three points are situated on a line nearly north and south, about 4 to 5 miles west of the Champlain or Logan fault; the distance between (2) and (3), and (4b) is about 12 miles. All the other points are west of this line; (4a) is just 2 miles west of the line and is distinctly Richmond.

In Mr. John A. Dresser's report on St. Bruno mountain, Quebec,[1] a list of fossils collected about that mountain is given and is said to indicate "Utica rather than Lorraine". The determinations were made by Dr. J. F. Whiteaves, Dr. E. O. Ulrich, and Dr. R. Ruedemann. This district is about 7 miles east of St. Hilaire station, and about 6 miles a little east of north of Chambly.

It would appear then, that there is a tract of Richmond strata in a belt of from 10 to 12 miles in width, with a development of Utica on the western margin and perhaps some Trenton along the east, near the fault line. It is hard to see how any Lorraine can be present in the localities from which the fossils are said to come. It will require a thorough study, with the solution of this problem in view, to decide the matter, and it seems to be of sufficient importance to warrant such an investigation being made.

[1] Memoir No. 7, Geol. Surv. Can., 1910.

CHAPTER III.

PHYSIOGRAPHY

GENERAL FEATURES OF THE ST. LAWRENCE LOWLANDS.

The lowlands of the St. Lawrence lie between the Laurenti plateau on the northwest, and the Appalachian mountains to tl southeast; they are about 80 miles wide at Montreal, and exte from the city of Quebec westward to Lake Huron, a distance over 600 miles. These lowlands are divided into two parts by narrow spur of the Laurentians which extends southeastward acr Ontario, crosses the St. Lawrence river at the Thousand Islan and spreads out to form the Adirondack mounta' of New Yor

The southwester ivision has a diversified character; t slightly small nd less diversified portion, to the northeast the dividing line, is the one with which this paper is concern It is a relatively flat plain, in which any irregularities have be largely hidden by a thick mantle of glacial drift. This drift 100 feet thick in places, and has been reworked, in part, by lat submergence so that the upper portion is sorted and stratifie The plain is traversed in a northeasterly direction by the St. La rence river and with comparatively low altitudes along the riv rises inland to maximum heights of about 400 feet above sea-lev

A striking break in the general uniformity of the plain is ma by the group of hills, the Monteregians, which rise abruptly fr it at intervals of about 10 miles, along a line nearly due east Montreal.

The Laurentian plateau to the northwest is an uplifted penepla now in process of dissection. It represents the northern nucle of the North American continent and forms a great horsesh shaped area about Hudson bay with an area of about 2,000,0 square miles. The plateau has a general altitude of about 1,5 feet above the sea, but rises to a maximum of over 6,800 feet the mountains in northern Labrador.

The Appalachian mountain system is represented in Quebec by the northern extension of the Green mountains in the form of three lines of hills running in a northeasterly direction, in a broad curve, and ending in the Shickshock mountains of Gaspe. For the most part, the summits are not more than 1,000 to 1,500 feet above the sea, though a few run up to a little over 2,600 feet. All have been subjected to glaciation which accentuated their subdued character acquired during an earlier cycle of erosion.

The Monteregian hills are a series of eight so-called mountains which extend across the St. Lawrence lowlands in an easterly direction from Montreal. They are of igneous origin; some are described as laccoliths and the others as volcanic necks. Their altitudes above sea-level are: Mount Royal, 769 feet; St. Bruno, 715 feet; Johnson, 876 feet; St. Hilaire (Beloeil), 1,375 feet; Yamaska, 1,500 feet; Shefford, 1,600 feet; and Brome 1,500 feet. Each mountain is surrounded by a hornstone collar which in most cases is cut into benches, forming terraces at different elevations. Most of the mountains have a steep northern face and a gentle slope to the south, which has been described as "crag and tail" structure; most of them present in plan the form of a horseshoe-shaped ridge, opening southward, surrounding an interior basin.

The St. Lawrence river flows northeastward through the St. Lawrence lowlands, and, with its tributaries, drains the lowlands and the whole southern portion of the Province of Quebec. The principal tributaries to the main river in southwestern Quebec are the Richelieu, Yamaska, and St. Francis, all of which converge towards the St. Lawrence and discharge at no great distance from one another. The grade on all of these streams is very low, and they run, for a great part of their course, over drift; rock exposures are few and are usually due to the presence of some dyke or sheet cutting the sediments and offering a relatively greater resistance to erosion. Morainic material deposited upon the retreat of the great continental glaciers has greatly interfered with the drainage, damming some streams to form lakes, and altering the courses of others.

EROSIONAL FEATURES.

The region of the St. Lawrence lowlands has been subjected erosion presumably ever since late Palæozoic time, and evidence this is impressed on, and recorded in the present day topograph For instance, the plain is developed on horizontal strata and steeply inclined beds without distinction. That erosive forc have swept away a great thickness of strata is evidenced by many the Monteregian hills which are surrounded by collars of metamo phosed sediments reaching in some cases to over 800 feet abo the plain, with bedding horizontal: and furthermore, since th igneous rock composing the tops of the hills is coarse-grained an clearly of a plutonic nature, it is reasonable to suppose that a thi ce r must have been removed before the plutonics were expose

The extent to which the region has been subjected to erosion also in part indicated by the blocks of lower Devonian limesto entrapped in the breccia on St. Helen island near Montreal an which are now at the level of the Utica shales. This is the on occurrence of Devonian strata within 80 miles of Montreal, an within 20 miles, there is a development of 2,000 feet of sha (Richmond) overlying the Utica, so it may be assumed that the have been stripped off the plain together with an unknown thic ness of the Silurian and Devonian formations. The superpose drainage gives a further proof of great denudation.

To sum up, then, it would seem that much more than 2,00 feet of sediment has been eroded since late Palæozoic time, an that the region at the present time is very near base level.

SUGGESTIONS OF AN OLDER BASE-LEVEL.

It was noted above, that the plain of the St. Lawrence is bordere on the northwest by the Laurentian peneplain, now at an altitu about 1,500 feet above the sea, and on the southeast by a northeas ward extension of the Appalachian mountain system which may regarded as a portion of the New England peneplain, which no varies in absolute elevation from 1,000 to 1,500 feet. If these tw upland regions were planated at the same time it is to be expecte that corresponding base-levels would be established. It is he suggested that the gap between the two is bridged by the summits of some of the Monteregian hills; a glance at the altitudes shows that the five largest hills are over 1,250 feet in height, and that the highest (Shefford) is only 1,600 feet above the sea.

Another feature bearing on this suggestion is that St. Hilaire (Beloeil) mountain has three of its four major portions at the same altitude, 1,375 feet, despite the fact that one of them is composed of a much denser rock than the others; these are all relatively flat on top although the sides in many places slope at an angle of over 30°, or take the form of cliffs. The four parts of the mountain are separated by well-developed wind-gaps opening into the interior basin; the highest one of these is about 350 feet above the lake or 950 feet above the sea. They seem to be remnants of an old drainage system which had been superposed on the mountain, and which is being cut down and gradually destroyed by the present streams.

It is interesting to note that the only one of the V-shaped gorges which is cut in rock (the others being cut in glacial debris) is floored with blocks of rock, of which many are erratics; hence it appears that this cut had been made before the advent of the glaciers and was protected from ice-action by its position. This shows that the topography of a preceding cycle of erosion was in process of rejuvenation probably because of uplift, before the Pleistocene.

CHAPTER IV.

STRUCTURAL FEATURES OF ST. HILAIRE (BELOEIL AND ROUGEMONT MOUNTAINS

As will be shown in the chapter on the petrology of St. Hila mountain, its igneous core is the product of two main intrusions an essexite, followed by a porphyritic nephelite-sodalite-syeni Upon approaching the centre of the essexite mass from any dir tion, there is noticed a more or less gradual change from t medium-grained, normal essexite at the border, into a vari which is very coarse-grained, and which is also characterized b certain streaky or banded structure of the whole mass, due to t arrangement, in alternate layers, of the different mineral consti ents. The most conspicuous mineral in this banding is a li grey, plagioclase feldspar which occurs in large platy cryst averaging from 1 to $1\frac{1}{2}$ inches on the side, with a thickness from $\frac{1}{16}$ to $\frac{1}{8}$ of an inch; these are arranged with their two lon axes in approximately a vertical plane. In a few places a distinc parallel arrangement of the flat faces of the feldspar is to be se but this is not by any means the general rule; rather, there is eddying effect together with a diverging and converging of li of crystals, and hence of the bands separating them, so that tl appear to merge into one another; the effect produced resemb the lines of flow in a stream, where the channel alternately wide narrows, and maintains a straight course.

A closer study of the rock shows that the long feldspars are f quently slightly curved, often in two or more places in rever directions, and that the bands between the feldspars are made of pyroxene, hornblende, and black iron ore. It is further s that there are many shorter laths of feldspar which are not orien parallel to the larger ones, but which cut across the bands at angle; this is also true for some of the crystals of pyroxene, but general direction of the pyroxene crystals is roughly the same that of the banding in which they occur.

The detailed description of this rock, both megascopic and microscopic, is given in the chapter on petrography (variety No. 2 of the essexite). In a section across one of the flow bands, the long feldspars are bent at intervals with increase of twinning lamellæ, and have uneven extinction at these points. There is no evidence of slicing of crystals, and none of granulation except that pieces of feldspar crystals of an earlier generation are included poikilitically in the long individuals and in the ferromagnesian minerals. The augite and the hornblende crystals occur in stout prisms, irregularly bounded, and arranged at random between the long feldspars, and at times enclosed in them; they are clearly of earlier crystallization than the large feldspars, which were the last to form.

It is clear that these minerals are all primary and not the products of later recrystallization. The lack of definite parallelism in the banding, and the winding course of the lines of crystals, together with the lack of deformation by slicing, granulation, gliding, etc., and the positive evidence of the primary nature of the minerals, seem to prove conclusively that the flow-like structures were produced before final solidification of the magma, and not by later deformation. The strained character of the long feldspars shows the result of movement in a viscous magma, and their orientation, with flat surfaces nearest to the vertical, indicates that the direction of general movement was approximately vertical.

In résumé, the central part of the essexite mass shows a flow structure from which it appears that the magma had an upward movement during the viscous stage, just before final solidification.

Structures analogous to that just described have been noted by several observers. Professor Frank D. Adams[1] in 1893 described a flow banding developed in the anorthosite of the Morin district in the Province of Quebec, Canada. He notes not only this peculiar structure but also a decided change in texture from that of the normal rock type. He says: "Wir haben hier also einen Fall vor uns, wo ein zweifellos eruptives Gestein mit vollig mässiger, wohl entwickelter ophitischer Structur allmählich in ein gestreiftes übergeht, dabei wird die gebändete Structur durch bedeutende Aenderungen, nicht nur in der Korngrösse, sondern auch in dem Mengenverhältniss der Bestandtheile herbeigefuhrt."

[1] Adams, Frank D., "Ueber das Norian oder Ober-Laurentian vom Canada"; pp. 451, 452.

"An dem oben beschriebenen Ausschluss wurden durch w
holtes sorgfältiges studium im Felde Thatsachen aufgefunde
auf eine Bewegung während des fleuerflussigen Zustandes hi
ten. Die Ungleichmassigkeit in der Korngrösse ist primai
sicher nicht durch Druck hervorgerufen; die streifen oder
gelmässigen Bänder nehmen nicht von vorne herein eine besti
Richtung an, sondern winden sich zuerst herum, weil we
Masse im zahflussigon Zustanden sich bewegt hätte, und werde
dann mehr gleich gerichtet, wenn ein Grund dafur da ist,
die Strömung sich auf eine bestimmte Richtung beschrä
müsste."

A more or less similar structure was noted by George H. Wil
in the gabbros of Maryland, in which he says: "In other c
more or less pronounced banded structure is produced by an
nation of layers of different grain or by such as have one con
ent developed more abundantly than the others. Such banc
not, however, parallel, but vary considerably in direction and sl
tendency to merge into one another, as though they had been
duced by plastic flow."

Some of the other Monteregian hills show this phenomenon
it has been used as a proof that they are true necks. In the
quoted above, Dr. Adams notes the occurrence of flow stru
in the essexite of Mount Royal. In a later paper[2] he desc
in Mount Johnson a "banding or fluidal arrangement of the cr
in the essexite" well exposed in quarries on the mountain
This arrangement is seen to be vertical, and the strike of the
ing "curves around the mountain, following its marginal out
Mount Johnson is described as "a neck in the most typical f
The essexite of Mount Yamaska shows banded structure in
places, and tabular feldspars one inch in breadth occur here
St. Hilaire. John A. Dresser has also noted a banded stru
in the essexite of St. Bruno mountain.

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[1] Williams, C. H., "The Gabbros and Associated Hornblende
occurring in the Neighborhood of Baltimore, Md": Bull. No. 28, U.S.
Surv., p. 26.

[2] The Monteregian Hills: A Canadian Petrographical Pro
Jour. Geol., Vol. XI, No. 4, p. 279, April-May, 1903.

C. K. Leith, in his "Rock Cleavage" (Bull. No. 239, U. S. Geol. Surv.), notes the parallel arrangement of tabular feldspars in the banded gabbros of the Adirondacks and northeastern Minnesota, the nepheline-syenite of central Wisconsin, the porphyritic gneiss from the main shaft of the Hoosac tunnel, Mass., and certain other labradorite-porphyries from America and Europe (page 199). He notes (on page 17), that such structures may be due to rotation of random particles during flowage of the magma, "although the parallel development of minerals in situ, due to differential stresses set up in the rock during the later stages of its cooling, may be more important than the rotation of random original particles."

Brögger is strongly of the opinion that the forces in a cooling viscous magma are unequal in different directions; that at any point they may be resolved into three mutually perpendicular differential stresses.[1]

In a paper on the "Banded Structures of some Tertiary Gabbros in the Isle of Skye" by Sir A. Geikie and J. J. H. Teall,[2] there is described a beautifully developed banding due mainly to segregation of the light and dark minerals. The differentiation is thought to have taken place before reaching its present position and the banding produced by "deformation of the molten mass during intrusion." There is no particular difference in grain, and the crystals interlock uniformly throughout, showing the whole to be the product of one intrusion. There is no cataclastic structure as evidence of regional metamorphism, to account for the structure, and the crystals do not show alignment as a rule.

It would seem, then, that a banded structure is not uncommon in deep-seated basic magmas. It is seen to be marked (1) by differences in granularity, (2) by segregation of the light and dark constituents, (3) by alignment of prominent mineral constituents, or (4) combinations of these one with another, pointing to different conditions of formation. Again, the bands may be parallel to one another, parallel to the periphery of the mass, parallel to both or to neither of them.

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[1] Leith, p. 150.

[2] Quart. Jour. Geol. Soc. Lon., V. 50, 1894, pp. 645-660.

Conditions numbers (1) and (2) frequently occur in combina with the banding roughly parallel to the periphery but not to another, and condition number 2 is noted well developed wl the bands are parallel to one another but not to the periph the former would be the result of flowage in a confined magm some definite direction, with a rotation of the crystals show much inequality in dimension, together with a certain segrega of constituents not so pronounced as in the second case, wl the conditions seem to be more favourable.

The nephelite-sodalite-syenite mass of St. Hilaire mountain a strong development of breccia about its borders, in which m of the fragments are of essexite, hornstone, and marble. breccia grades off into the normal syenite, but even in the inte of the mass there are some inclusions to be found.

There are three large blocks of limestone and marble encl in this magma, two of which are over 500 feet in length and feet in breadth. Dr. Ells has stated[1] that a Devonian limes containing *Centronella hecate* and *Zaphrentis prolifica* had found on St. Hilaire mountain, and a sketch map indicating location of this occurrence was kindly loaned the writer by fessor Adams. The exposures in this place show a few fe shaly limestone, passing into purer limestone, and fine-grai light grey marble; the beds are on edge with a strike and dip w closely corresponds with the cliff jointing of the hornstone 30 to the north. A large quantity of this material, mostly of the l stone, was shipped to New Haven and closely examined for fo Professor Schuchert has made the following determinations:

"Crinoid columnals of a large, rounded, thick stem.

Cyclospira bisulcata (Emmons). Rare.

Cyclospira n. sp. Exceedingly abundant. As the speci are uniformly small and occur by the thousands, it is prol that they are mature individuals. They are, however, very like the larger *Cyclospira bisulcata*.

Isochilina n. sp. Nearest to *I. ampla*, but the valves are s what smaller, narrower, and relatively more elongate.

[1] Communication to Professor Frank D. Adams.

This horizon is clearly in the Trenton, and probably in the lower part of this formation."

All the limestones observed in this area have the same appearance and contain the Cyclospira in great abundance in certain layers. The other two occurrences are of coarse, impure marble and no fossils were to be found. To bring it to its present position this block of Trenton limestone must have been raised at least 1,000 feet. The limestone reported by Dr. Ells was not seen by the writer, but if the determination of the Devonian fossils was correctly made, and those cited are not easily mistaken, the block in which they occur must have dropped vertically over 300 feet. It would then appear that there had been a certain amount of churning in the magma, a feature which is characteristic of volcanic necks.

An examination of the strata of the sedimentary collar about the igneous mass of the mountain shows that the beds have not been deformed, but that they have been indurated by thermal waters and heat from the magma, converting the shale into hornstone, and the sandy layers into quartzite. The more porous strata have been altered a greater distance from the mountain than the dense. The general covering of drift prevented extensive study of the contact phenomena. The plan of the contact of the igneous mass as a whole bears no relation to the topography, showing that the magma rose in a vertical channel. Both the essexite and syenite intrusions are elliptical (nearly circular) in outline with the major axis running north and south. The circular form would give the maximum volume for least friction surface to the passing magma.

In summary then, the evidence of undisturbed country rock; the coarse texture of the igneous mass close to the outer contact; the vertical conduit through which the magma passed; the striking development of flow structure in the essexite; and finally, the churning action shown in the syenite, all point to the conclusion that St. Hilaire mountain represents an eroded volcanic neck.

The evidence at Rougemont mountain is not so positive, but is still suggestive. The texture of the igneous mass is coarse-grained close to the contact, and there is a strong development of breccia about the borders, but, so far as observed, the fragments are entirely of hornstone, so that no vertical mixing of strata can be

shown to have taken plac in this case. The contact is, in p
wavy line, without regard to the t geography, and this fact, to
with the cliff development on the north and south sides, show
the conduit of the magma was practically vertic.

In the petrographical study of the igneous rocks of the mo
it developed that while the mountain is the product of one
intrusion, there were two successive periods of injection, o
lowing almost immediately after the other. The olivine-yam
which occupies the eastern part of the mountain was fol
before it had become consolidated, by an injection of a grea
of rougemontite, which sent apophyses into the yamaskit
developed fine flow-banding in many places.

In résumé, then, the facts brought out are: (1) That t
trusion has taken place forcibly, breaking off the strata and
ing many fragments in a border breccia; (2) that the ext
the mass is coarse-grained close to the contact; (3) that the c
through which the magma arose is vertical;(4) that there
dence of flow within the magma. The suggestion is the
strong that Rougemont represents an eroded volcanic neck

The tables accompanying the chapter on the Mont
Hills give a brief summary of the geological history of the M
gian province. It is seen that the four central mounta
volcanic necks and that the two to the east are laccoliths
the evidence from the western occurrences is indefinite, al
Mount Royal is very probably also a neck. The most
volcanic activity apparently occurred in the central part
Province, and towards its western end. The close grou
such a number of volcanic necks goes to show that the
magma could not have been at a great distance below the s
The close association in origin of the several mountains
more than one intrusion has occurred, is brought out by th
of these intrusions, and the correspondence in rock-type is s
this is more fully discussed under general petrology.

The rough linear arrangement of these mountains was n
Logan and it was suggested that this probably indicated a
disturbance, perhaps faulting. Suggestions appear in d
reports that the location of the separate Monteregians

termined by the loci of intersection points of a set of parallel fractures crossing the main line of disturbance in a north-south direction. No evidence of this faulting was observed at either St. Hilaire or Rougemont mountains, so, as no additional data are at hand, the evidence is summed up by two quotations from Dr. Ells' report[1] as follows:—

"Of the two mountains last described, it may be remarked that the more easterly, viz., that of Brome, and Shefford, occurs along the line of contact between the Cambro-Silurian and Cambrian rocks, while Yamaska Mountain is situated on the line of fault between the Sillery division of the Cambrian and the Lower Trenton formation. It is probable that the Shefford and Brome extrusion is also along a fault line, the presence of which is not so clearly indicated as that on which Yamaska Mountain lies, though the amount of dioritic matter is much greater at Brome."

"Beloeil, or St. Hilaire Mountain . . . . is due north from Mount Johnson, and, on the hypothesis that these eruptive masses come up along north-south lines of fracture, would probably lie in the continuation of the fault which extends from near Lacolle to St. John."

It does not seem clear that there is any positive evidence to show that there are lines of faulting related to these intrusions. On the contrary, it is usually found that volcanic necks, such as are found here, occur without any dependence upon fault systems, and that the magma, with its gases under high pressure, has drilled its way through the strata without disturbing the bedding. Examples of occurrences of this kind are well described from the diamond-bearing craters of South Africa,[2] the volcanic necks of central Montana,[3] and the volcanoes of the Mount Taylor region, New Mexico[4]

[1] Report on the Southwest Sheet of the "Eastern Townships" map (Montreal sheet). Ann. Rept. Geol. Surv. Can., Vol. VII, Pt. J, p. 73.

[2] Hatch and Corstorphine, "Geology of South Africa," etc.

[3] Pirsson, L.V., Bull. 237, U. S. Geol. Surv., 1905.

[4] Johnson, D. W., Bull. Geol. Soc. Am., Vol. XVIII, pp. 303-324.

CHAPTER V.

PETROLOGY: ST. HILAIRE (BELOEIL) MOUNTA

The igneous rocks composing St. Hilaire (Beloeil) mount are of two main types: essexite, and nephelite-sodalite-sye Each of these types has a number of varieties, and there is a s dykes representing the last stages of each of the main intrusi The essexite was the first to be intruded and it is coarse-gra up to the contact with the sedimentary collar; the central por shows a very distinct flow structure with the development of l platy feldspars standing on edge, giving an indication of move in an upward direction. At various places in the essexite, br hornblende becomes prominent; in one occurrence the ferro nesian minerals are very small in amount and labradorite nephelite greatly predominant. It is proposed to call variety *rouvillite*.

The syenite at its borders forms a typical intrusion-br which occupies a zone of varying width, and foreign rock fragm are found widely scattered throughout the whole area of the sye The border variety of this type approaches a tinguaite in text and a number of peculiar, unknown minerals are developed. main mass has a porphyritic texture, and, in places, appea have differentiated, forming a rock very high in sodalite, whi here called feldspathic tawite.

ESSEXITE: TYPE VARIETY.

As is the case in nearly all basic magmas, the essexite v considerably both in texture and in mineral composition; at same time one cannot, as a rule, point out any distinct pha being confined to one or more particular areas. The ce portion of the mass exhibits a flow structure with a parallel arra ment of platy feldspars, not seen about the borders. Owin the great difficulty of obtaining fresh rock in some places, by blasting, the selecting of type material was governed by condition. The type selected for detailed description and analysis represents the normal granitoid rock but is a little higher in feldspar than the average rock. It was taken from the northwest face of the mountain where a perpendicular cliff overlooks the village of St. Hilaire and the huge blocks offer abundant fresh material. Departures from this type will be indicated later, and described as varieties of the type.

The rock is holocrystalline, medium-grained, spotted black and white, and possesses an uneven but sharp fracture. The feldspar has a light grey colour and is a little more abundant than the dark minerals; it occurs as irregular crystals and in distinct laths up to 7 mm in length by 0·5 mm in width. Glittering biotite crystals, 2 to 4 millimeters by 2 mm, are easily distinguishable, and the hornblende and augite can be readily determined. Minute crystals of titanite may also be observed, but the other mineral constituents cannot be made out.

The thin section shows the presence of apatite, pyrite, iron ore, titanite, zircon, olivine, augite, biotite, hornblende, labradorite, and nephelite, listed in the order of their crystallization, as well as small amounts of secondary minerals: chlorite, serpentine, and muscovite.

Apatite, which seems to have crystallized first, occurs in short, rounded prisms, abundant in some slides. *Pyrite* is present in a few irregular grains. The *iron ore* has, in many cases, well-marked outlines and usually forms the nucleii of crystals of biotite. *Titanite* occurs in a few irregular grains. *Zircon* is present in two or three minute crystals. *Olivine* occurs in a few irregular grains, and shows a slight decomposition along cracks to a yellowish green serpentine. The *augite* has a very light grey colour, with a faint pleochroism to reddish violet, indicating the presence of titanium: the crystals have a maximum size of 2 mm with rounded, or subangular outlines. Extinction takes place up to 43°, and twinning is common on (100). *Biotite* is fairly abundant, often surrounding iron ore, and usually as irregular crystals up to 1·5 mm in length by 1 mm in breadth. Pleochroism is from a pale yellow to a deep reddish brown, and the very deep absorption is striking. A few flakes show a radiating structure due to a breaking down to chlorite and iron ore.

Hornblende is present in amount usually about equal to tha
the biotite, but in some places it is more abundant. Crysta
a brown variety range up to 2 mm by 1 mm in size, some of
smaller crystals showing good outlines. A green variety oc
usually as borders to either the augite or the brown hornble
but seemingly not as a decomposition product; it is altoge
subordinate to the brown in quantity. The brown variety
be more fully treated in the description of variety No. 1 of esse
Plagioclase is in laths reaching 4 mm in length by 1 mm in brea
the laths are irregularly bounded and often show zonary struct
It shows well-developed albite and carlsbad twinning and hen
easily determined by the method of Michel Levy. It ra
between Ab_2An_3 and Ab_1An_2. The variety is thus seen to
between andesine and labradorite. *Nephelite* occurs filling
gular openings about the feldspar laths; it is easily distingui
by an incipient alteration to muscovite.

CHEMICAL ANALYSIS.

The chemical analysis given below shows that the rock is a
mal variety of essexite.

SiO_2	49·96%
Al_2O_3	18·83
Fe_2O_3	2·52
FeO	6·64
MgO	3·52
CaO	7·42
Na_2O	5·25
K_2O	2·58
TiO_2	2·40
H_2O	0·60
P_2O_5	0·25
Rest	0·20
	100·17

According to the Qu·· titative Classification of Igneous R
the essexite belongs to class 2, dosalane; order 8, norgare; ra
salemase; subrang 4, salemose.

The mode was calculated from measurements made by the method of Rosiwald, and is as follows:—

	% by vol.	Assumed sp. gravity.	% by wgt.
Labradorite	55·0	2·67	48·70
Nephelite	4·5	2·6	3·87
Augite	19·0	3·4	21·41
Brown hornblende	6·0	3·4	6·76
Biotite	5·5	2·9	5·30
Iron ore	5·0	5·2	8·61
Apatite	3·0	3·2	3·18
Olivine	1·5	3·3	1·62
Titanite	0·5	3·5	0·60
	100·0		100·05

This is, of course, only an approximate result, since the specific gravities had to be assumed for the different minerals; this error was minimized as much as possible by taking averages of several determined specific gravities for minerals exhibiting properties similar to those in this case.

To determine roughly the specific gravity of the whole rock:—

Labradorite	48·72%	×	2·67	=	130·1
Nephelite	3·87	×	2·6	=	10·1
Augite	21·41	×	3·4	=	72·9
Hornblende	6·76	×	3·4	=	23·0
Biotite	5·30	×	2·9	=	15·8
Iron ore	8·61	×	5·2	=	44·8
Apatite	3·18	×	3·2	=	10·2
Olivine	1·62	×	3·3	=	5·3
Titanite	0·60	×	3·5	=	2·1
					314·3

Specific gravity of rock as calculated	3·14
Specific gravity determined	2·92
Difference	0·22

ESSEXITE: VARIETY NO. 1, RICH IN BROWN HO BLENDE.

This variety occurs in a few scattered places, mostly, how within the central part of the essexite area; that is, in the coarsely crystalline part exhibiting flow-structure. The spe here described comes from the centre of the south face of tl in the northwest part of the mountain; that is, from just of the centre of the whole essexite mass.

The appearance of this variety is intermediate between that normal granitoid essexite described as the "type," and th phyritic variety with the large platy feldspars, described as v No. 2. The dark minerals are only slightly in excess of the ones; all are millimeter- to centimeter-grained, giving a m appearance to the rock; and the platy feldspars are subpa giving the rock an uneven cleavage parallel to their long dimen Flashing prisms of pyroxene, averaging over 5 to 8 millimet length, are abundant, arranged with their long axes roughl plane parallel to the feldspars. Hornblende occurs more a antly than the pyroxene, in stout prisms which vary in siz which tend to be bunched.

The following minerals in their order of crystallization ar in thin section: apatite, iron ore, olivine, pyroxene, brown blende, and plagioclase. It may be noticed that the mi occurring in the "type" specimen which do not appear i variety, are: zircon, biotite, green hornblende, and nephelit

Apatite is abundant in short, stout laths, and in hexagona sections. *Iron ore* is in irregular grains, and small octahedr so abundant as in the "type" variety. *Olivine* is in one or two rounded crystals, embedded in the hornblende. *Pyroxene* oc a few crystals sometimes intergrown with the hornblende; it same as that described as occurring in the "type" variety. *blende* is very abundant in stout crystals averaging about 5 length; they are irregular in outline and are bunched so th have interfered in one another's development. The min also found intergrown with the augite. Pleochroism is prono as follows: **c**=**b**, deep brown; **a**, pale brownish yellow absorption is **c**=**b**>**a**, and the extinction **c**∧c=14°. Th blende is thus seen to be a barkevikite. The manner of intergrowth of hornblende and augite, which is so common in this essexite, is such as to very clearly show the primary origin of both minerals. Similar intergrowth has been noted by Iddings in the rocks of Electric Peak and Sepulchre mountain.

Plagioclase occurs in laths over 8 mm in length, and in pieces of laths, or plates of varying width. There is a subparallel arrangement to the long crystals, but the broken ones appear often to be wedged cross-wise, often giving uneven and wavy extinction. The long individuals are frequently bent, producing the same phenomena as noted later in the typical flow-variety. Measured by the method of Michel Levy, this plagioclase is found to be more basic than the average in the magma; it varies from Ab_3An_7 to Ab_1An_4; that is, from labradorite to bytownite.

The *texture* of the rock is very similar to that of variety No. 2.

ESSEXITE: VARIETY NO. 2.

This phase forms an elliptical mass in the centre of the essexite body, shows distinct flow-structure, and grades into the normal granitoid rock on all sides. The exposure in the field shows a dark coloured rock, usually very coarse-grained, and characterized by large platy feldspars ½ inch to 1½ inch on the side and $\frac{1}{16}$ inch to ⅛ inch in thickness, which are arranged in eddies or frequently in typical flow-structure with the flat sides of crystals parallel. The rock is high in iron and is frequently coated with brown iron oxide.

The hand specimen shows a grey and black banded rock, in which the black constituents are pyroxene, hornblende, and iron ore; the white mineral is a plagioclase. The gneissic arrangement of the minerals is very well developed in some specimens and a subparallel arrangement is general in the whole phase.

Under the microscope the minerals present are seen to be: apatite, iron ore, plagioclase, augite, and brown hornblende. Olivine and nephelite are absent. *Apatite* is abundant in large, irregular masses, usually enclosed by the ferromagnesian minerals. *Augite* occurs in stout prisms up to 2 mm in length, with irregular outlines and, usually, intergrown with brown hornblende. It has a slight pleochroism from light grey to a reddish grey, and shows

distinct schiller structure. *Brown hornblende* is present in va[…]
amount, sometimes much less abundant than the augite, some[…]
greatly preponderating. It is the same as described in the ess[…]
variety No. 1. It occurs usually intergrown with the a[…]
but also in distinct, irregularly bounded crystals, ranging up[…]
mm in length, and with well marked cleavage.

Plagioclase is present in two generations, in roughly bou[…] laths, reaching in length to over 2·0 mm and to 2 mm in w[…] They are well twinned according to both the carlsbad and the[…] laws, and measured by the method of Michel Levy, they pro[…] be mostly labradorite Ab_1An_1 to Ab_2An_3, with some andesine, Al[…] Some of the crystals containing andesine have a tendency to[…] zonal structure. The crystals have a parallel arrangement[…] smaller ones often penetrate, or are enclosed by, the ferromag[…] minerals, but the larger laths enclose crystals of all the[…] minerals and are grouped in bands, separated by bands of th[…] minerals, producing a regular gneissoid arrangement. Th[…] crystals frequently enclose fragments of smaller crystals of fe[…] as well as masses of ferromagnesian minerals arranged poikilit[…] The long individuals have been subjected to strain and show[…] ing of the lamellæ in reversed curves with a discontinu[…] twinning lamellæ along the crystal and an increase in the n[…] of lamellæ about points of bending, together with a wavy [...] tion from these places along the length of the section.

In *texture* the rock is millimeter- to centimeter-graine[…] inequigranular; the crystals are multiform, and irregular. fabric is hiatal and poikilitic, in which the large feldspars fo[…] oikocrysts, and the ferromagnesian minerals the xenocrysts. oikocrysts are magnophyric, tabular, and equiform, and ar[…] in lines producing a linophyric texture. The relative prop[…] of crystals is xenoikic, and the xenocrysts are relatively m[…] sized, multiform, and diverse. There is a tendency to[…] structure where the smaller laths of feldspar penetrate the bisi[…]

ESSEXITE: VARIETY NO. 3.

A medium to fine-grained rock, dark greenish grey in[…] occurs in an exposure about 700 feet south of the Pain de[…] It is about 3 feet × 2½ feet in area, and sticks cornerwise [...]

mass of coarse essexite which is highly weathered and crumbles easily for some distance around; field observations do not give a clear idea as to whether the mass is a dyke, or an inclusion; it seems to be surrounded by essexite, however.

The minerals seen in thin section are: orthoclase, olivine, brown hornblende, biotite, apatite, and iron ore, listed in the order of importance. Chemical test failed to reveal any feldspathoid present. *Orthoclase* makes up over 70 per cent of the rock. It occurs in stout laths 0·5 mm to 10 mm in length, and the uncertain birefringence shows it is not a pure variety. Carlsbad twinning occurs in a few crystals. It is very probably a soda-orthoclase. The other minerals are as described in the normal essexite.

The rock is phanerocrystalline to microcrystalline, decimillimeter-grained, and inequigranular. The crystals are irregular, multiform, and tend to form a seriate-intersertal aphyric fabric.

The striking feature of this variety is the presence of abundant olivine in a rock so high in orthoclase.

ROUVILLITE.

This shows a peculiar phase of the differentiation; it is really an extreme variety of the essexite, but, for reasons given below, it is treated as a distinct rock type. Its description is as follows:—

Holocrystalline: medium- to coarse-grained; light grey colour, spotted with black. Highly feldspathic, the orthoclase in slender laths up to 15 mm in length by 4 mm in width, but mostly less in width, the nephelite not well outlined, but recognized by its dull, greasy lustre and a light greenish colour. Hornblende and augite crystals have well-developed cleavage and are 2 to 5 mm by 3 mm in size.

The minerals seen in thin section are: apatite, iron ore, titanite, hornblende, augite, plagioclase, and nephelite, given in their order of crystallization. *Apatite* is in short prisms up to 0·5 mm in length, quite abundant. *Iron ore* is not so abundant as in the "type" variety of essexite. *Titanite* is in a few irregular grains, in one case enclosing apatite. *Hornblende* is as described before,

but with a stronger absorption. It is much less abundant th
the "type" variety of essexite. *Augite* is about equally abun
with the hornblende; it shows a stronger pleochroism than in
"type" variety of essexite. It has the following pleochrois
a = light greyish purple: **b** = light purplish red: **c** = colou
absorption **b** > **a** > **c**; extinction, **c** $\wedge$ c = 41°.

Plagioclase is the most abundant mineral in the slide, occurri
laths up to 11 mm by 2 mm in size. It shows well-devel
albite and carlsbad twinning, and varies between Ab_1An_1 and
An_4; that is, from labradorite to a medium bytownite. A ce
amount of intergrowth is also developed. *Nephelite* forms a
one-fourth of the whole section; it occurs filling interstitial sp
and as intergrowths with the plagioclase; partial decompos
to muscovite makes it easily recognizable.

The rock is millimeter-grained for the most part, the
crystals of apatite and of some of the ferromagnesian indivi
being decimillimeter-grained; it tends to be equigranular, an
crystals are multiform and irregular. The frequent intergrowt
plagioclase and nephelite give rather a graphic texture to the

CHEMICAL ANALYSIS.

The chemical analysis of this rock type is given below, w
table of analyses of other rocks for comparison.

Table of Analysis.

	1	2	3
SiO_2	51·26	49·96	47·67
Al_2O_3	23·78	18·83	18·22
Fe_2O_3	1·81	2·52	3·65
FeO	2·70	6·64	3·85
MgO	1·96	3·52	6·35
CaO	8·00	7·42	8·03
Na_2O	6·72	5·26	4·93
K_2O	2·16	2·58	3·82
H_2O	0·55	0·07	2·97
H_2O	0·10	0·53	
TiO_2	1·66	2·40	....
P_2O_5	....	0·25	....
MnO	0·10	0·20	0·28
Total	100·00	100·18	100·15
Sp. g.	2·77	2·92	......

1. Rouvillite, St. Hilaire mountain, M. F. Connor, analyst. (Analysis incomplete).
2. Essexite, St. Hilaire mountain. M. F. Connor, analyst.
3. Theralite, porphyritic, Elbow creek, Crazy mountains, Montana. (With 0·38% of hygroscopic water).
4. Shonkinite (Amphibole-malignite). North shore of Poobah lake, Rainy River district, Canada.

Note.—Analyses Nos. 3 and 4 are taken from Rosenbusch, "Elements der Gesteinlehre," p. 176.

A comparison of these analyses shows that the chemical composition of rouvillite is very similar to the three types quoted. It is higher in alumina and soda, and lower in magnesia and potash than the normal theralite.

According to the Quantitative Classification of Igneous Rocks, the rouvillite belongs to class 2, dosalane,; order 8 norgare; rang 3, salemose; subrang 4, salemase.

The following is a calculation of the mode of rouvillite, based on microscopic measurement by the method of Rosiwald.

	% by vol.	Assumed specific gravity.	% by wgt.
Nephelite	29·35	2·60	27·38
Plagioclase	55·90	2·67	53·42
Pyroxene	7·50	3·4	8·98
Hornblende	3·64	3·4	4·45
Pyrite	2·50	5·0	4·48
Apatite	1·15	3·2	1·33
Total	100·04		100·04

To determine the specific gravity of the rock:—

Ne	27·38%	×	2·6	=	711
Plag	53·42	×	2·67	=	1450
Pyrox	8·98	×	3·4	=	306
Hb	4·45	×	3·4	=	151
Py	4·48	×	5·0	=	224
Ap	1·33	×	5·2	=	43

Calculated spec. gravity	2·885
Spec. gravity by weighing	2·77
Difference	0·11

The mode shows that the rock contains over 80 per cent o
constituents, and that this is made up of 27·38 per cent of nep
with 53·42 per cent of labradorite and bytownite. The r
really a theralite, but since the typical theralite contains pr
inant ferromagnesian minerals, it is thought advisable to disti
this variety and the name "rouvillite" is suggested after the
in which the mountain occurs.

NEPHELITE-SODALITE-SYENITE: TYPE VARIE

The syenite mass shows numerous variations from the n
depending largely upon its relations to inclusions, or to the
with surrounding rocks; these variations will be described as
ies of the type. The rock from the southeast face of the
the southeast end of the mountain, near the top, is fresh, fr
inclusions, and represents the type porphyry as it appear
not changed by foreign causes.

The hand specimen is phanerocrystalline with a porp
texture; large phenocrysts of feldspar and feldspathoid occ
fine-grained groundmass of minute crystals of feldspar and g
aêgerite: the whole mass is peppered with larger aêgerites o
0·5 mm length. The rock thus presents a greyish green
ance, spotted with large, glassy feldspathoid, and light grey fe

Thin sections show the following min rals: aêgerite,
nephelite, sodalite, eudialyte, and orthoclase, with a fe
crystals of laven like mineral. There has been crystal
in two generation of the aêgerite, and a continuous gr
feldspars. The albite and aêgerite started to crystallize a
the aêgerites stopped at a very small size. The nephelite an
ite came next and attained large crystals, holding small a
and feldspars. About the same time eudialyte, and the
generation of aêgerite appeared, also holding inclusions of th
minerals; the orthoclase came aft r the eudialyte. The l
like mineral contains inclusions of most of the other mine
appears to have crystallized near the last. The groundm
aggregate of laths of feldspar and aêgerite with a trachyt
ture, and containing many fragments which were torn f
larger aêgerite crystals. Both the nephelite and eudialy
indications of a certain amount of corrosio by the mag

Aêgerite-augite occurs in very minute laths and in large crystals up to 2 mm by 1 mm in size. It is very abundant, the small laths being included in all the other minerals, and the larger individuals penetrated by both orthoclase and albite crystals. A zonary banding is evident in the large crystals, in which the borders are lighter coloured. Frequently the minute aêgerites form a line parallel to, and just within, the large nephelite borders. Absorption —**a** = pea green; **b** = brownish green; **c** = yellow green; $\mathbf{a} > \mathbf{b} > \mathbf{c}$; $\mathbf{a} \wedge \mathbf{c} = 6°$.

Albite occurs in laths in all stages of growth up to 1·5 mm in length; it shows fine albite twinning but not many carlsbad twins. It is included, in small crystals, in all the other minerals, and forms intergrowths with nephelite and sodalite. *Nephelite* appears in phenocrysts up to 2 mm by 1 mm in size, although there are many smaller crystals in the groundmass. It is about equally abundant with the sodalite, together forming over 50 per cent of the section. Intergrowths with albite and orthoclase are seen in some crystals, and the border arrangement of the aêgerite inclusions is quite noticeable. The crystals are relatively fresh, but show ragged edges as if corroded by the magma.

Sodalite, like the nephelite, is seen in both large and small crystals about the same size as the nephelite. It often shows idiomorphic boundaries to the nephelite, and its edges are not corroded; intergrowths with albite are rare. The sodalite is relatively free from inclusions and is completely isotropic. It is comparatively fresh, showing no decomposition product. *Eudialyte* is described more fully in connexion with the contact variety of this type; the mineral here is very light pink to colourless and occurs in rounded or subangular crystals about 0·5 mm in diameter. *Orthoclase* occurs in irregular laths about 0·3 mm in length. It is not so abundant as the plagioclase, and it often shows an uneven or patchy extinction. A *lavenite-like mineral* occurs in one or two small, ragged crystals; it will be described more fully in the case of the contact varieties where it is more abundant and in larger crystals.

The type-specimen is decimillimeter- to millimeter-grained with some larger phenocrysts; it is inequigranular and has a hiatal, porphyritic fabric. The crystals are multiform and irregular; the ratio is dopatic, and the phenocrysts are usually mediophyric,

and arranged in clusters, forming a cumulophyric texture. Th
groundmass is holocrystalline, and, excepting the minute crysta
and fragments of aêgerite, the rock may be said to be seriat
porphyritic; there is a break, however, between the largest phen
crysts and the more seriate portion. The whole mass has a trach
tic structure, with a roughly parallel arrangement of the long ax
of crystals, and flow-structure around phenocrysts.

CHEMICAL ANALYSIS.

The analysis of this variety together with others, introduc
for the sake of comparison, is given below.

Table of Analysis.

	1	2	3	4	5	6
SiO_2	54·74	54·20	53·28	54·14	56·45	49·
TiO_2	trace	1·04	....	0·95	0·29	....
ZrO_2	....	....	....	0·92	....	0·
Al_2O_3	21·53	21·74	20·22	20·61	20·08	23·
Fe_2O_3	4·06	0·46	1·56	3·28	1·31	3·
FeO	0·94	2·36	1·99	2·08	4·39	1·
MnO	0·14	....	....	0·25	0·99	0·
CaO	0·90	1·95	3·29	1·85	2·14	0·
MgO	0·18	0·52	0·29	0·83	0·63	0·
K_2O	4·18	6·97	6·21	5·25	7·13	4·
Na_2O	12·84	8·69	7·89	9·87	5·61	14·
Cl	....	....	....	0·12	0·43	2·
H_2O	0·35	0·22	3·43	0·40	1·77	1
P_2O_5	....	....	....	....	0·13	....
	100·25	100·25	99·93	100·55	100·45	101

1. Nephelite-sodalite-syenite. St. Hilaire mountain, Que. M. F. Con analyst.
2. Nephelite-syenite, Serra de Monchique, P. Jannasch, N. Jahrb. f. M 1884, II, p. 11.
3. Nephelite-syenite, Magnet cove (Arkansas). J. F. Williams, Rept. Geol. Surv. Ark., 1890, II.
4. W. Ramsay and V. Hackman, "Der Nephelinsyenit des Umtek." Fe II, 2, Helsingfors, 1894, p. 196.
5. Pulaskose (sodalite-syenite), Square Butte, Mont. W. H. Melv analyst. L. V. Pirsson, Bull. 237, U. S. Geol. Surv., p. 68.
6. Sodalith-syenite, feldspathreich, mit eudialyte ebenda. Rosenbu Gesteinlehre, p. 126.

According to the Quantitative Classification of Igneous Rocks, the syenite belongs to class 2, dosalane; order 7, italare, rang 1, lujavrase; subrang 4, lujavrose.

The mode of this rock calculated by the method of Rosiwald is as follows:—

	% by vol.	Assumed sp. g.	% by wgt.
Sodalite	17·5	2·2	14·6
Nephelite	34·8	2·6	34·2
Orthoclase	9·4	2·6	9·3
Albite	23·2	2·6	22·8
Aêgerite	11·0	3·5	14·6
Eudialyte	4·0	2·9	4·5
	100·0		100·0

To determine the specific gravity of the rock:—

So	14·6%	×	2·2	=	321
Ne	34·2	×	2·6	=	889
Or	9·3	×	2·6	=	242
Ab	22·8	×	2·6	=	593
Aêg	14·6	×	3·5	=	510
Eu	4·5	×	2·9	=	130

Calculated sp. g	=	2·685
Determined by weighing	=	2·68
Difference		0·005

The abundance of sodalite is worthy of note, so the rock has been called, nephelite-sodalite-syenite.

NEPHELITE-SODALITE-SYENITE: CONTACT VARIETY.

This is characterized in many cases by finer grain in the groundmass, but with phenocrysts about the same size as in the normal type. There is a tendency for the phenocrysts to collect in bunches and in the groundmass there is a massing of minute laths of plagioclase, and of aêgerite, into mattes. There is a general trachytic structure which is very pronounced in some cases, not so strongly in others.

Accompanying the slight change in texture is a mineralogical difference in that the border varieties contain a much higher percentage of eudialyte, and of the låvenite-like mineral mentioned before, together with an unknown, colourless mineral in some cases. These minerals may be described at this place.

Låvenite-like Mineral. This occurs in stout crystals and attains a size of 1·3 mm by 1 mm. Its properties are: bright yellow colour; one good cleavage; biaxial; negative; index of refraction about 1·7; birefringence 0·035 prox.; extinction 0°–17°, usually less than 10°; pleochroism: **a** = orange; **b** = yellowish brown; **c** = brownish yellow; absorption **a** > **b** > **c**.

This mineral differs from astrophyllite and lamprophyllite, both in pleochroism, and in having inclined extinction. It resembles the låvenite described by Hackman[1] as occurring in the nephelite-syenite of Umptek, in which the pleochroism is: **c** = orange yellow; **b** = straw yellow; **a** = bright wine yellow; absorption **c** > **b** > **a**. Extinction $\mathbf{c} \wedge a = 17°$. If **a** and **c** were interchanged, the correspondence would be almost exact.

An unknown colourless mineral occurs in irregular crystals; one measures 3 mm by 2·5 mm but they are usually smaller. It was one of the last minerals to form, and is crowded with inclusions of the other minerals. It has the following properties: colourless; index about 1·65; biaxial; negative, birefringence about 0·017; extinction parallel; plane of the optic axes parallel to cleavage.

Eudialyte. The mineral described under this head occurs in subangular to rounded grains and sometimes stout laths. It is colourless, sometimes carmine, and in many cases the same crystal is part coloured and part colourless. It is probable that there is here some eudialyte and some eukolite, for some of the crystals appear to be positive, while others show a distinctly negative character. The coloured variety is only observed near the margin of the syenite mass, and the colour is usually confined to the borders or to the centre of the crystals; it is accompanied by a certain cloudiness as if from decomposition, while the rest of the crystal is quite clear.

[1] Ramsay and Hackman, Fennia II, 2, p. 146. Helsingfors, 1894.

No cleavage is visible, but in the elongated crystals, sometimes **o** is parallel to the long axis, sometime **e**, and in each case the absorption is from carmine to colourless or yellowish, and the absorption **o**$\gtrless$**e**. The birefringence is very low, and optical anomalies are not uncommon; there is a tendency to hour-glass structure in some cases. W. Ramsay[1] found an isomorphous mixture of eudialyte and eukolite in eleolite-syenite from the peninsula of Kola. The double refraction was sometimes partly positive and partly negative; extinction $=0$. An hour-glass structure is very common in these occurrences. Biaxial anomalies occurring in eudialyte have been noted by N. V. Ussing[2] in nephelite-syenite from Greenland, and by J. F. Williams from Magnet cove, Arkansas. In these [illegible] angle changes in one and the same crystal, and can rise [illegible] $=50°$; the absorption **o**$>$**e**.

Lacroix observed a eukolite mineral in an aêgerite-foyaite dyke in Ampangarinara, in northwest Madagascar,[3] in which there was strong dispersion, and the centre was less coloured than the periphery of the mineral. In his work on "Les Syenites Nepheliniques de L'Archipel des Los et Leurs Minera[illegible]",[4] he describes eudialyte in which the pleochroism is as follows:—

o = Ng or Np = rose carmine
e = Np or Ng = colourless or yellowish.

"On voit que la coleur est lies à une direction cristallographique et non aux indices." Lacroix also notes that, while the birefringence is sometimes uniform in section, it is more often variable in the same individual, not by concentric zones, but by irregular "alveoles"; frequently also it is seen to diminish along the fissures.

NEPHELITE-SODALITE-SYENITE: BRECCIA VARIETY

The nephelite-syenite mass is bordered in most cases by a development of breccia in which are enclosed fragments of many different rock varieties; theralite, essexite, nephelite-syenite, feldspathic

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[1] Fennia, III, No. 7, 42. Helsingfors, 1890.

[2] Mineralogisk-petrografiska Undersogelser af Gronlandske Nefelinsyeniter og beslægtede Bjaergarter.

[3] Extrait des Nouvelles Archives du Museum, 4 serie, Tome 1.

[4] Extrait des Nouvelles Archives du Museum, 5 serie, Tome III.

tawite, tinguaite, camptonite, hornstone, limestone, and marble are all represented. In many examples the inclusions seem very slightly altered; in others, where flow structure is well developed, the smaller fragments have been drawn out into flat lenses, and are more intimately associated with the magma; in still other cases the fragments have been partially digested in the nephelite-syenite, leaving parts of characteristic minerals to tell the tale. Close to the border the number of inclusions is great and the matrix is very fine-grained; towards the centre of the mass they become widely scattered, but are not entirely absent. In size, the fragments range from a couple of inches in diameter to the great masses of limestone and marble which are hundreds of feet in length. Some of the interesting features of mineral change or development in this breccia will be described.

In the inclusions of essexite, the augite and olivine are more or less altered to chlorite and to serpentine. Pyrite is developed along fissures and frequently occurs in thin lines between the minerals, giving each a framed effect. In intergrowths of hornblende and augite, the augite is often completely decomposed, leaving the hornblende fresh, and in other cases, the latter also is changed to a bluish green chlorite: the feldspars are not greatly affected. Except in individuals showing good cleavage, decomposition begins at the periphery and works towards the centre of the mineral.

Where essexite has been digested in syenite, there occur bunches of fragmentary crystals of ferromagnesian minerals, and skeletons of iron ore, about which feldspar has crystallized, giving a hornfels appearance to the slide. The pyroxene is sometimes aêgerite, or nearly so, and in other cases it has a centre of titaniferous augite, with distinct pleochroism, surrounded by a band of lighter violet tint, and an outside border of green pyroxene with a much smaller extinction; this border resembles a secondary growth. Intergrowths with brown hornblende are seen in some of the green crystals which are now an aêgerite-augite. There is also abundant biotite with strong pleochroism.

Near the contact with the larger inclusions of marble, the syenite magma shows a development of new minerals, particularly near the northern inclusion; here the magma has differentiated rather thoroughly in a few spots, developing a white rock made up of minute laths of feldspar with an occasional crystal of aêgerite, and also a green variety, in which the aêgerite occurs in tufts and forms a regular matte. Scattered through both of these types, more or less abundantly, are prisms of a blue hornblende which have well-bounded outlines, and the terminal faces in some are clearly shown. This mineral is described as follows:—

The mineral has a very strong dispersion of the optic axes, with no absolute extinction, but a sudden change of birefringent colour from brown to prussian blue; a zonary structure becomes very marked during the change. Crystal faces are well developed, both prismatic and terminal, and the crystals range in size from 1 mm. downward. The pleochroism is as follows: **a** = greenish blue; **b** = brownish blue; **c** = light grey-blue to light, yellowish green. The absorption is **a** > **b** > **c** and extinction **a** $\wedge$ c seems to be in two phases, one commonly about 18°, and the other reaching a maximum of 40°. The mineral is positive. The pleochroism agrees most closely with that of arfedsonite described by Ussing[1] from Greenland, in which he notes: **a** = greenish blue; **b** = blue to grey blue; **c** = greenish grey to yellow. Absorption **a** > **b** > **c**, and optically negative. It differs from this mineral in being positive. The positive charact n arfedsonite from Greenland is noted by Brögger in the ". a. lien der Syenite-Pegmatit Gange," Norwegen, 1890.

Rosenbusch draws attention[2] to the usual association of arfedsonite with aêgerite, and notes its occurrence in lujavrite, pantellerite, and nephelite-syenite generally.

There is another mineral, occurring in the feldspathic part of this rock, which is very peculiar, and its properties do not correspond with any known mineral. Its characters are: colourless, or palish yellow; index of refraction = 1·6 approx.; birefringence = 0·02—0·025; uniaxial; positive; probably tetragonal. The mineral suggests melinophanite, but differs from it in the direction of cleavage (parallel to (001) distinct in the former,) and in being optically positive. The variety of the rock containing this mineral has a peculiar groundmass made up of albite, orthoclase, and ne-

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[1] Meddelelser om Gronland, Kopenhagen, XIV, 1899, p. 191.

[2] Mikrosk pische Physiographie, Mineralien, p. 243.

phelite, of which the albite forms the longest laths, 1·2 mm in length, and also some of the smallest; the albite crystals are frequently arranged in radiating tufts, and all have very irregular boundaries due to mutual interference in crystal growth. There is a general parallelism of crystals on the whole, producing a trachytic structure.

TAWITE: FELDSPATHIC TYPE.

This rock is really a variety of the nephelite-sodalite-syenite, and so is treated in this place. This variety of the main magma has been found at three different localities, on the borders of the syenite mass. Near the northeast contact just south of the included mass of limestone and marble, there are coarsely crystallized fragments of the rock included in the syenite. This was the only place observed where the field relations are definite. The other two localities are near the centre, on the east and west contacts of the syenite. The occurrence on the east is coarsely crystalline and appears to be in place, but the exposure is too limited to show its relations positively. The specimen from the west side was collected by Mr. LeRoy some years ago, but the writer did not find this particular occurrence. It is medium to fine-grained, and shows blue sodalite, together with streaky segregations of feldspar; it looks rather similar to the normal syenite, and might easily be overlooked in the field.

It appears, then, that this variety is in part earlier than the main mass of syenite, and that part may be due to a differentiation in the magma during intrusion. It is quite likely that there are other localities where this rock occurs under the drift, for the very limited amount of total exposure makes it probable that only a small proportion of any one scattered type would be visible. The specimen submitted for analysis is of the coarse grained variety, and was 'collected by Mr. LeRoy from near, or at the place, near the northeast contact, where fragments were found included in the syenite proper.

The rock is phanerocrystalline, and has the appearance of a mosaic of well-bounded crystals of feldspathoid, in a matrix of white feldspar together with a few small crystals of pyroxene and a little black iron ore; the latter, however, is mostly in scattered masses

It has a light grey colour and breaks with uneven fracture. The crystals of feldspathoid range from 2 to 7 millimeters across, and are in the form, usually, of hexagons or squares; they are rather closely packed and greatly exceed the finer groundmass in amount.

The minerals seen in thin section are: aêgerite, plagioclase, orthoclase, nephelite and sodalite, listed in their order of crystallization. A colourless zeolite is very abundant in minute needles in the sodalite. *Aêgerite* is in two generations; in very small crystals included in all the other minerals, and in a few larger crystals, 1 mm. in length, which enclose small feldspars; its properties are similar to those of the aêgerite in the main type of syenite. *Plagioclase* occurs only in minute laths, with well-developed albite and carlsbad twinning; measurements prove it to be albite, nearly $Ab_6 An_1$. *Orthoclase* occurs in laths and in irregular crystals; it is more abundant than the albite and sometimes attains a length of 5 mm; the usual length, however, is about 1 mm.

Nephelite is in subangular crystals ranging around 1 mm in length, and containing inclusions of all the earlier minerals, and some needles of a colourless zeolite. *Sodalite* is so abundant that crystal boundaries can be discerned only by noting the disconnected line of other minerals about its borders. The central part of the crystals is comparatively free from inclusions of aêgerite, feldspar, and nephelite, but is crowded with minute needles of a colourless zeolite. The *zeolite* is a colourless mineral, occurring as needle-inclusions, and in long hair-like crystals in the nephelite and sodalite. It has the following properties: index of refraction is about 1·48; double refraction 0·012; parallel extinction; A is parallel to the axis of elongation. It is one of the natrolite group and differs from natrolite in the last property mentioned. The needles are too minute for further determination.

The rock is millimeter-grained for the most part, and inequigranular. The crystals are multiform and irregular, and form a hiatal, poikilitic fabric. The relative amount of the crystals is peroikic; the xenocrysts are relatively small, and are frequently arranged parallel, and near to the borders of the oikocrysts. The oikocrysts tend to form a seriate-intersertal fabric.

CHEMICAL ANALYSIS.

A chemical analysis of this rock is given below, with other analyses for comparison.

	1	2	3	4
SiO_2	41·84	45·2[illegible]	49·29	54·74
TiO_2	0·00	....	....	trace
ZrO_2	....	....	....	....
Al_2O_3	28·42	27·37	15·46	21·53
Fe_2O_3	3·29	3·53	12·00	4·06
FeO	0·40	0·49	2·35	0·94
MnO	0·15	0·19	trace	0·14
MgO	0·25	0·33	1·32	0·18
CaO	0·66	1·22	1·61	0·90
Na_2O	19·48	17·29	14·74	12·84
K_2O	2·06	3·51	1·23	4·18
H_2O	0·14	....	....	0·35
H_2O	0·62	0·40	....	trace
P_2O_5	0·04	....	....	trace
Cl	4·47	....	....	....
CO_2	0·00	....	....	....
Loss on ignition	....	....	1·85	....
	101·82	99·61	97·85	99·86
O. Cl	1·10	....	....	....
	100·72			

1. Feldspathic tawite. St. Hilaire Mt., Que., M. F. Connor, analyst.
2. Urtite, Lujaur-Urt. Halbinsel, Kola, Rosenbusch, Gesteinlehre, p. 126.
3. Tawite, Lujaur-Urt. Halbinsel, Kola. H. Blankett, analyst. Fennia 15, Helsingfors, 1899, p. 25.
4. Nephelite-sodalite-syenite, St. Hilaire Mt., Que., M. F. Connor, analyst.

The analyses would seem to show that the St. Hilaire occurrence is more typical tawite than the original described by Ramsay; the resemblance to the analyses of urtite is very striking. This type differs from the original tawite in being higher in alkalis and alumina, and lower in silica and ferric iron.

According to the Quantitative Classification of Igneous Rocks, the tawite belongs to class 1, persalane, order 8, ontarare; rang 1 peralkalic; subrang 5, persodic; section 4, dosonic.

It is interesting to note that this is one of the few rock types which may be classified with advantage, even to the section. There is no name corresponding to this variety, in the quantitative classification, so it is proposed to call it *Belocilose* after the mountain on which it occurs.

Measured microscopically, the minerals are not present in constant proportions in the several varieties of this rock; the mode of the one for analysis will be here given.

	% by vol.	Assumed specific gravity.	% by wgt.
Sodalite	70	2·2	65·2
Nephelite	8	2·6	8·6
Orthoclase	12	2·6	13·2
Albite	5	2·6	5·6
Aêgerite	5	3·5	7·4
	100		100·0

In the more commonly used system of classification of igneous rocks, the proportion of feldspar to sodalite in different main divisions of the syenite family and in the above described rock, is somewhat as follows:—

syenite............feldspar : sodalite : : 100 : 0
sodalite syenite.....feldspar : sodalite : : 50 : 50
feldspathic tawite..feldspar : sodalite : : 23 : 77
tawite.............feldspar : sodalite : : 0 :100

It is at once seen that this rock comes between sodalite-syenite and typical tawite, on account of its abundant feldspar; the name most suited for this rock is thus feldspathic tawite.

VARIATIONS IN THE TAWITE.

(1) The finer grained variety from near the eastern contact resembles the one just described very closely in essential characteristics. It differs from the latter in that:—

(*a*) The feldspar is nearly all microperthite, an intergrowth of orthoclase and albite.

(*b*) Biotite is found intergrown with aêgerite, and the latter occurs in crystals about 1 mm in length; it is less in amount than in the former case.

(*c*) There are a few crystals of titanite present.

(2) The western variety is coarse-grained, and differs from the type described in that it:—

(*a*) Contains more feldspar and aêgerite.

(*b*) Contains abundant eudialyte.

(*c*) The feldspar tends to occur in bunches. This variety closely resembles the border type of sodalite, in that it is coarser, rather than finer, in grain than the main mass.

(3) Many of the fragments of this rock, that are found embedded in the syenite proper, have the sodalite completely replaced by zeolite for a distance of about 3 inches from the contact; the rest of the sodalite is relatively unaltered. This zeolite is reddish coloured, fibrous and radiating; it has parallel extinction, low double refraction, and A parallel to the long axis; except for the latter quality it closely resembles natrolite. An interesting feature is that little specks of calcite occur dotted through the zeolite, showing that the original mineral contained some lime. In places where the sodalite is hardly altered, the nephelite is completely decomposed to cancrinite, and the unaltered sodalite in these fragments had frequently a bluish tinge. This variety is low in aêgerite, and contains no eudialyte.

DYKE ROCKS.

CAMPTONITE.

Occurs in dykes from a few inches up to 1·5 feet in width. It is found cutting the essexite, and one 16 inch dyke cuts the hornstone in the Riviere des Hurons, about 1[illegible] miles below St. Jean Baptiste. These dykes vary in mineral composition, and in texture, to a certain extent; so there are found all gradations into an essexite, of which camptonite itself is the representative hypabyssal type. The type camptonite will be described under this heading; it outcrops on the path to the Pain de Sucre, at an elevation of about 1000 feet.

The rock is phanerocrystalline, but very fine grained. It has a medium grey colour and a few small laths of feldspar hardly break the monotony in the even grain of the rock; the other minerals can not be readily distinguished.

The minerals seen in thin section are: zircon, iron ore, apatite, hornblende, biotite, plagioclase. *Zircon* occurs in many small grains through the rock. *Black iron ore* and *pyrite* occur in irregular grains throughout the rock. *Apatite* is abundant in long, slender laths, and in rounded grains. *Hornblende* is found in irregular crystals varying from 0·1 to 0·5 mm in length. It is very abundant, forming about 35 per cent of the rock, and it has the following properties: pleochroism $\mathbf{a}$ = light brown; $\mathbf{b}$ = dark brown; $\mathbf{c}$ = brown; absorption is $\mathbf{b} > \mathbf{c} > \mathbf{a}$ with extinction $\mathbf{c} \wedge c = 10°$. It is a variety of the basaltic hornblendes, resembling the Rougemont variety, and that from Bohemia (Levy and Lacroix). The *biotite* is in irregular flakes reaching a length of 0·5 mm and is rather abundant. It has a strong pleochroism from a yellowish brown to deep reddish brown.

The *plagioclase* occurs in laths with irregular boundaries and was determined as varying between andesine and labradorite. All the individuals show carlsbad twinning, but the albite lamellæ are very faint in many cases and are hardly visible. Uneven extinction is common, and there is a tendency to zonary structure. The greater part of the plagioclase crystallized after the ferro-magnesian minerals, but had begun to form at an earlier stage; this is shown by inclusions of feldspar in the hornblende and biotite.

The structure shows a tendency to be ophitic; the crystals are decimillimeter in grain, and tend to be seriate. It is interesting to note that these rocks do not exhibit the "hampshiroid" habit of the typical camptonite as described by Washington[1] from the Belnak mountains, N.H.

CAMPTONITE: VARIETY NO. I.

The camptonite from the Riviere des Hurons differs from the one just described in that the hornblende occurs in slender laths as much as 1·5 mm in length, and also in short, well-bounded prisms with an average length of 0·2 mm. The plagioclase which occurs in narrow laths is frequently found in bunches or in nests about some mineral which has been replaced by calcite. There is a certain amount of light grey, non-pleochroic augite present, which is partly decomposed, forming calcite.

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[1] Am. Jour. Sci., Vols. XX and XXII, p. 502.

CAMPTONITE: VARIETY NO 2.

This occurs in a dyke 30 inches wide cutting the essexite and also t[illegible] of type camptonite described above; it is exposed on the path leading to the Pain de Sucre.

[illegible] rock is phanerocrystalline, with a medium to fine grain. [illegible] medium grey colour, and appears to be composed of dark [illegible] hornblende, in slender crystals averaging 2 to 3 millimeters [illegible] embedded in a groundmass of crystals of a white feldspar. [illegible] amount of feldspar is slightly greater than that of the dark constit[illegible]

The [illegible] seen in thin section are the same as those noted in the type camptonite, with essentially the same properties and characteristic[illegible] hornblende shows a stronger pleochroism than that in the former case, from a brownish yellow to a deep brown, and the extinction, $\mathbf{c} \wedge c$ is as high as 13°; otherwise the properties of the minerals coincide very closely; the essential difference is one of texture. The rock is holocrystalline, decimillimeter to millimeter-grained, and inequigranular. The crystals are multiform, irregular, and seriate. A few long, narrow crystals of hornblende give a tendency to a porphyritic texture.

CAMPTONITE: VARIETY NO. 3.

This occurs as a 12 inch dyke cutting the essexite, and is exposed on the path to the Pain de Sucre about 800 feet before reaching the summit. It is a fine-grained, phanerocrystalline rock with a medium grey colour, and the only minerals distinguishable are hornblende and pyroxene in a few widely scattered phenocrysts. Under the microscope this variety differs from the normal type in containing abundant titanite and titaniferous augite. The titanite occurs in irregular grains and in characteristic wedge-shaped crystals, and it is idiomorphic to the other minerals except zircon, which is found enclosed in it in minute crystals. The pyroxene is in irregular grains and crystals and in well-bounded prisms averaging 0·2 and 0·3 mm in length; the cleavage is poorly developed. It is slightly pleochroic from $\mathbf{a}$ = greenish grey to $\mathbf{c}$ = yellow-grey, $\mathbf{c} \wedge c = 38°$.

CAMPTONITE: VARIETY NO. 4.

A 2½ inch dyke cuts the hornstone near the south contact of the essexite. It is dark grey in colour, and microcrystalline, but shows a few phenocrysts of augite about 1 mm in length; it is also dotted with small patches of pyrite. Under the microscope it is seen to be made up of phenocrysts of light grey augite, and of plagioclase, in a groundmass of feldspar and iron ore, together with products of decomposition. The augite is frequently highly decomposed and its borders show a slight resorption. It is at times intergrown with biotite. Chlorite and iron ore are products of the decomposition. The larger feldspars, 0·5 mm in length, show a zonary banding; they vary from labradorite to andesine in composition, the more basic forming the central bands. The crystals are gathered in bunches in the groundmass. The small feldspars are frequently arranged parallel to the borders of the phenocrysts.

COMPARISON OF VARIETIES OF CAMPTONITE.

Tabular Statement.

Variety	Hornblende	Pyroxene	Titanite	Texture.
Type....	Very abundant	...	Some.	Ophitic: very fine-grained.
No. 1 ..	Very abundant	Little...	Some.	Fine-grained.
No. 2..	Very abundant strongly pleochroic.		Some.	Slightly porphyritic; medium to fine-grained.
No. 3.	Abundant. ..	Abundant.	Abundant.	Slightly porphyritic fine-grained.
No. 4..	Abundant. ..	Abundant.		Pilotaxitic and slightly porphyritic; fine-grained

The amount of feldspar in these types is fairly constant, the table simply summarizes the change in mineral composition and in texture.

NEPHELITE-SYENITE.

Nine dykes of this class are exposed in a narrow strip of hornstone about 300 feet in length, on the south side of the mountain within 100 feet of the essexite contact. They were not observed to cut the latter, and a covering of drift obscures the relationship. The dykes of this group vary in width from 4 inches up to 32 inches.

The nephelite syenite dyke rocks of St. Hilaire may be classed under three varieties, namely:—

(*a*) Variety containing aêgerite-augite alone; (*b*) variety containing aêgerite-augite and green hornblende; (*c*) variety containing aêgerite alone. These are phanerocrystalline, medium- to fine-grained rocks having a little grey colour in the feldspathic variety, but becoming darker as the percentage of ferromagnesian minerals increases. There is some difference in granularity in the different dykes, and often in the same dyke. The minerals are not always evenly distributed throughout the rocks; the result is the appearance of a banded structure in which the bands merge, in places enclosing narrow lenses of coarse and fine material, or of light and dark colour, without definite arrangement, except that it is roughly parallel to the enclosing walls. A few of the dykes are breccias containing fragments of hornstone, essexite, and of very fine-grained camptonitic material. The majority of the dykes are of variety (*b*) and the pyroxene is easily distinguishable in small well-bounded crystals, and in laths, some of which show very irregular outlines.

The nephelite is easily distinguished by its glassy appearance contrasted with the light grey colour of the feldspars; the former occurs in irregular crystals, and the latter in well-developed prisms. In variety (*a*) the aêgerite-augite and feldspar give rather a porphyritic tendency to the rock; no hornblende is visible. This variety cuts the former variety (*b*) showing it to be of later origin. Variety (*b*) will be described in detail.

Thin sections show the rock of variety (*b*) to be made up of titanite, zircon, apatite, iron ore, pyrite, biotite, aêgerite-augite, hornblende, plagioclase, orthoclase, nephelite, and sodalite. The feldspars and feldspathoids crystallized about the same time. Alteration products are cancrinite, fluorite, iron ore and biotite.

Titanite is abundant in many of the dykes, in characteristic wedge-shaped crystals, and in small irregular masses; *zircon* occurs in the feldspathic phases usually, in short, stout, subangular crystals; *apatite* in small amount is found in well-bounded laths, and basal sections, in the types high in bisilicates.

Black iron ore and *pyrite* occur in small, irregular masses throughout the rock; they are not very abundant. *Biotite* in some of the dykes is abundant; in others it is altogether wanting; it occurs in scattered, ragged, crystals and has a pronounced pleochroism from light yellow to a dirty, greenish brown. *Pyroxene* is very abundant in some of the dykes and resembles an arfvedsonite very closely, except for the cleavage, which is nearly at right angles, and often brighter polarization colours. It occurs in irregularly bounded prisms and in well-defined basal sections, some with eight sides, some with six. The colour varies in intensity; in different dykes, and even in the same dyke it changes from a deep green to an almost colourless variety. Many crystals have a deep green border about a lighter green interior. In some sections, where hornblende is prominent, there is seen an intergrowth of the green and colourless varieties of pyroxene. The deep green variety has a decided pleochroism as follows. **a** deep green; **b** green; **c** yellowish to brownish green. The absorption is $\mathbf{a}>\mathbf{b}>\mathbf{c}$ and the extinction $\mathbf{c}\wedge c$ is variable, frequently 3° or less; it goes up as high as 28°, and the colourless variety is still higher, reaching 38°. The pyroxene varies from a nearly pure aêgerite to nearly pure augite, and is, therefore, an aêgerite-augite. The green pyroxene resembles closely the aêgerite-augite described by Hackman[1] as occurring in the ijolite from Kaljokthal, except that the pleochroism in the present case is more pronounced, $\mathbf{a}=\mathbf{b}>\mathbf{c}$, grass green to yellowish green; extinction $\mathbf{a}\wedge c$ always less than 30°. He notes zonary structure, and attributes the changeable extinction in part to this. A very similar occurrence of aêgerite-augite is described by L. V. Pirsson[2] from the Bearpaw mountains, Montana, occurring in tinguaite-porphyry.

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[1] Fennia, II, 2, Helsingfors, 1894, p. 182.

[2] Am. Jour. Sci., Vol. II, 1896, p. 190.

Hornblende occurs sparingly with the pryoxene, but in some dykes is quite abundant. The hornblende prisms tend to become segregated into masses in the rock, surrounded by feldspar and feldspathoids. In the dyke where it is most abundant, the crystals are not well bounded; they average less than 0·5 mm in size, and are roughly equi-dimensional. Cleavage on basal and prism sections is well developed. The pleochroism is as follows: **a** = yellow-brown; **b** = deep brownish green; **c** = brownish green; absorption **b**>**c**>**a**; and extinction **c**$\wedge$c = 16°-18°. This variety of hornblende has not received particular attention in standard text-books on petrography, but a variety which resembles it very closely is described by L. V. Pirsson[1] from the Highwood mountains, Montana, which has the following properties; pleochroism **c** = ochre-yellow; **b** = dark olive; **a** = dark olive-green; "The absorption is very strong and the arrangement rather peculiar **b**>**c**>**a**," and extinction **c**$\wedge$c is as high as 30°. Pirsson states that it is unlike any hornblende he knows, and that "It is much like arfvedsonite in a general way, and is at all events, considering its habitat and associates, one of the alkalie group of hornblendes." Closely associated with the green pyroxene and hornblende, fluorite is developed in the coarser parts of the dyke; it appears to be a product of pneumatolysis.

Orthoclase is not abundant usually; it occurs mostly in the feldspathic varieties, in laths which show carlsbad twins. *Plagioclase*, the most abundant mineral in some of the dykes, is a basic andesine, $Ab_1 An_1$, as determined by the method of Michel Levy. It occurs in stout laths, ranging from 0·3 mm up to 2·5 mm in length, averaging 1·5 mm. There is well-developed carlsbad and albite twinning, and intergrowths with orthoclase or nephelite are not uncommon. In most of the varieties the plagioclase is an intermediate andesine. *Nephelite* occurs most abundantly in the feldspathic variety of the rocks, and there it is found in crystals with nearly square shapes, 0·5 mm on the side. It is in larger crystals in some other of the dykes. It appears to have formed before the sodalite. It shows all stages of alteration to cancrinote, and contains inclusions of all the earlier minerals. *Sodalite* is absent in most dykes, but abundant in others; the determining factor seems to be the relative

[1] Bull. U. S. Geol. Surv., No. 237, p. 95.

abundance or absence of the green ferromagnesian minerals. It occurs in irregular patches and is easily detected by its cloudy appearance, and isotropic character. It is seen to be filled with minute anisotropic inclusions, and also contains laths of orthoclase and albite.

It appears that there are the following varieties among the dykes of this type:—

COMPARISON OF VARIETIES OF NEPHELITE-SYENITE.

Tabular Statement.

Variety	Aeg-Aug.	Aeg.	Hb.	Ne+So	Orth.	Plag.
No. 1...	Very little	....	Very little	Little	Little?....	Very abundant. $Ab_3An_2Ab_2An_3$.
No. 2...	Abundant.	....	....	Little.....	Little?....	Abundant Ab_3An_1 Ab_1An_1
No. 3...	Abundant.	....	Abundant.	Little.....	....	Much.
No. 4...	....	....	Much.....	Abundant.	Little.....	Much.
No. 5...	....	Abundant.	....	Abundant.	Abundant.	Much.

These dykes are all found within 1000 feet of the road to Lac Hertel about 100 feet south of the essexite contact. Nos. 4 and 5 are within 150 feet of the road, the others are grouped, about 800 feet farther. No. 1 is included in this group but appears to be a hypabyssal representative of the rouvillite described above.

TINGUAITE.

These dykes cut all the other dykes observed. They vary in width from 4 inches up to 3 feet, and are usually over 1 foot wide. None were found cutting the hornstone, and the majority were in the essexite. A few thin dykes of this type traverse the marble enclosed in the syenite.

This rock is microcrystalline, sparingly porphyritic, and in colour shows faint shades of grey, brown, and green, in different dykes; the rock as a whole has a greasy lustre. No minerals can be distinguished except in the widest dykes where a few phenocrysts of white, porcelain-like feldspar can be perceived.

With the use of the microscope on thin sections, this type is seen to contain the following minerals, in order of crystallization: zircon, aêgerite, biotite, eudialyte, plagioclase, orthoclase, nephelite, sodalite, and a lâvenite-like mineral. These do not all occur in the same dyke, however; for example, zircon and biotite are found in but one occurrence. The properties of all these minerals are very similar to those in the main mass of nephelite-syenite, so they will not be repeated. It is sufficient to add that the eudialyte has a bright carmine colour in this case, and that the extinction angle of the lâvenite-like mineral is only a few degrees, usually, with a maximum observed of 7°.

The rock is microcrystalline, micron-grained to decimillimeter-grained, and inequigranular. The crystals are hypidiomorphic and multiform, and tend to be hiatal and slightly porphyritic. The phenocrysts are of orthoclase, aêgerite, or the lavenite-like mineral, and minophyric to mediophyric; they are scattered, producing a skedophyric texture. The groundmass is graniphyric, with a trachytic arrangement of the small laths of feldspar. The minute crystals of aêgerite are at times more or less segregated in bands running through the rock without apparent order, merging into one another, or spreading out again into the groundmass. A bunching into radial groups of aêgerite laths is characteristic of many of the dykes, but a typical trachytic structure, in which the minute prisms of feldspar and aêgerite appear to "flow" around the phenocrysts, is usually well developed.

COMPARISON OF VARIETIES OF TINGUAITE.

Tabular Statement.

Variety.	Zircon	Lavenite.	Eudialyte.	Biotite.	Aegerite	Colour	Texture.
No. 1.	......	......	......	Little	Little	Medium to light grey.	Medium to fine-grained; ophitic.
No. 2.	......	......	......	......	Very abundant.	Green-grey.	Very fine-grained; trachytic.
No. 3.	......	......	Some.	......	Abundant.	Greenish-grey	Fine-grained; pilotaxitic; slightly porphyritic.
No. 4.	......	......	Much.	......	Abundant.	Dark grey	Fine-grained; trachytic.
No. 5.	......	Little	......	......	Very Abundant.	Grey-green	Fine-grained; porphyritic.
No. 6.	Much.	Much.	......	......	Abundant.	Brown.	Very fine-grained; trachytic.

Nos. 1 and 5 occur within 150 feet east of the road to Lac Hertel, in the hornstone exposure just south of the essexite contact.

No. 2 is found at an elevation of about 1,100 feet, on the path to the Pain de Sucre.

Nos. 3 and 6 cut exposures of essexite in the interior basin near the southwest side.

No. 4 is found with the nephelite-syenite dykes about 1,000 feet west of the road to Lac Hertel, 100 feet south of the essexite contact.

Variety No. 1.—A 4 inch dyke cutting the hornstone near the contact is composed principally of plagioclase, ranging from andesine containing about 35 per cent anorthite to labradorite with 60 per cent anorthite. The laths average from 1 to 2 millimeters in length, and have a subparallel arrangement. The other minerals present are nephelite, biotite, pyroxene, hornblende, titanite, apatite, and iron ore, in small amounts.

Variety No. 5.—This differs from the type in that the only bisilicate present is a light yellowish green aĉgerite, with very slight, if any, pleochroism. It occurs in irregular crystals ranging from a fraction of a millimeter up to 2·5 mm in length, sometimes in radiating bunches of smaller crystals. There are large crystals of orthoclase showing microperthitic intergrowth, and the plagioclase in this case is andesine with about 30 per cent of anorthite.

This variety occurs in a 4 inch dyke cutting two of the other varieties of this type.

SHEET ROCKS.

TINGUAITE.

Two sheets of this rock are exposed in the sediments about the centre of the east face of the mountain at an elevation of about 110 feet above sea-level. One of them crosses the wood-road about one-fourth mile east of the main contact and its bluish-green appearance serves to distinguish it from the hornstone. The thickness of this sheet could not be definitely determined since only the surface is exposed. About 300 feet to the west of the road, another sheet is exposed in a 25 foot cliff of hornstone. It is 5 to 6 feet in thickness and closely resembles the former one; they are separated by about 20 feet of hornstone. The lower sheet shows streaks and a few distinct layers of brown rock through it; the contact is sharp, so that the brown may be seen to wedge out horizontally. These layers are from one-half inch to 3 inches in thickness and are slightly coarser in grain; they appear to be due to a slightly later injection of the magma into the sheet.

These sheets are very fine-grained, with a bluish-green colour, and are studded, more or less thickly, with phenocrysts of a pea-green mineral, with good crystal faces, and octagonal outline; these crystals have a tabular development, averaging 1·5 mm in diameter and 0·4 mm in thickness, have no good cleavage, and a hardness about 6. Blow-pipe analysis failed to determine what the mineral is, so it is described as an unknown mineral. Near the contact with the sediment, the tinguaite becomes even finer and darker in colour. Thin sections show the main masses of tinguaite to contain the following minerals: apatite, aĉgerite, plagioclase, orthoclase, eudialyte, and an unknown colourless mineral near the contact with the hornstone; quartz is also present in small amount. Chemical tests failed to reveal any feldspathoid.

The *apatite* is in well-bounded laths and basal sections; it is fairly common. *Aĉgerite* is abundant in minute prisms, frequently forming matted masses; the pleochroism is from greenish blue to yellowish green. *Blue hornblende* in minute prisms forms a large percentage of the groundmass. *Plagioclase* is abundant in irregular laths. It is a basic oligoclase to acid andesine. It forms a few phenocrysts about 0·2 mm in length. *Orthoclase* is common, usually in larger crystals than the plagioclase. Carlsbad twinning is common. *Eudialyte*, a colourless mineral, closely resembling that described under this heading in the main mass of nephelite-syenite, is present in a few crystals.

Unknown Mineral.—The mineral is colourless; occurs in prisms; index about 1·8: birefringence 0·035; centre is filled with gas cavities; extinction is parallel; extension parallel to c; no cleavage showing; biaxial; negative, full of inclusions of the green granules, and of feldspar. There are ghosts of well-shaped crystals outlined by a brown iron-ore and fitting into the groundmass; none of the original mineral remains; but it was probably the unknown mineral just described.

The rock is microcrystalline, inequigranular. The crystals are hiatal and porphyritic, with a perpatic to dopatic ratio. The phenocrysts are mediophyric and prismatic, with a skedophyric arrangement. The groundmass is graniphyric and has a trachytic structure.

Chemical Analysis.

The following is an analysis of the blue-green tinguaite which is exposed on the wood-road to the east of St. Hilaire mountain.

SiO_2	60·00
Al_2O_3	15·33
Fe_2O_3	6·02
FeO	0·67
MgO	0·61
CaO	1·12
Na_2O	6·44
K_2O	8·15
TiO_2	0·40
H_2O-	0·08
H_2O+	0·32
MnO	0·63
Cl	0·09
	99·86
Less 0 = Cl	0·02
	99·84

According to the Quantitative Classification of Igneous Rocks, the tinguaite belongs to class 2, dosalane; order 5, germanare; rang 1, umptehase; subrang 3, ilmenose.

TINGUAITE PORPHYRY.

The brown variety differs in that there is more eudialyte, and some titanite present. The phenocrysts are larger and the trachytic texture more pronounced, especially around the large crystals.

APLITIC TYPE.

This occurs in a sheet extending into the sediments from the northeast end of the essexite mass, at an absolute elevation of 550 feet. The exposure on a small cliff is 4 feet thick, and it appears to thicken considerably towards the mountain.

The rock is medium to fine-grained, phanerocrystalline, and has a medium grey colour. Feldspar is the chief constituent; black iron ore and biotite are the only other minerals that can be readily distinguished; they are in small amount.

The minerals seen in thin section are: zircon, apatite, iron ore, biotite, tourmaline, feldspar, and quartz, stated in their order of crystallization.

Zircon occurs in a few small, well-bounded prisms. *Apatite* in slender laths, not abundant. *Iron ore* in a few grains averaging about 0·2 mm in diameter. *Biotite* in scattered, irregular flakes, in some cases showing chloritization. *Tourmaline* occurs in one small bunch of crystals; it is the blue variety with decided pleochroism: **o** = deep blue, **e** = pale blue to violet; absorption **o** > **e**. *Feldspar* is the most abundant mineral present. It is in stout, irregular laths, reaching 2 mm in length, often showing carlsbad twinning. The extinction is rather patchy, but parallel, and the crystals show alteration to kaolin. It is probably a soda-orthoclase. *Quartz* is rather abundant in irregular grains, filling interstices between the feldspars, and surrounding some of the small crystals. The rock is decimillimeter to millimeter-grained, and inequigranular; the crystals are irregular and multiform; the fabric tends to be seriate-intersertal and aplitic.

HORNFELS.

The sedimentary collar surrounding St. Hilaire mountain has been indurated to some extent by waters from the magma. The dark grey shale has been altered to a very typical hornstone, which closely resembles the one described by Rosenbusch[1] for the type of this rock. There are no idiomorphic minerals, but all are so peculiarly interwoven and interlocked that there is no apparent order, and their relative ages cannot be determined. The minerals present are: quartz, feldspar, muscovite, and biotite, and, in one case, zircon.

Biotite is abundant in small flakes, and gives the characteristic spotted appearance to the rock. The minerals do not contain the numerous specks of black material so often seen in rocks of this class, showing that the original shale was not highly carbonaceous.

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[1] Gesteinlehre, 1901, pp. 101-102.

CHAPTER VI.

PETROLOGY: ROUGEMONT MOUNTAIN

There are three main rock types in the Rougemont igneous mass which grade into one another, and whose contacts may be defined only arbitrarily. These types are distinguished by the relative abundance of feldspathic and ferromagnesian constituents, and the gradation is seen to take place from a highly feldspathic variety on the west, to a nearly pure ferromagnesian rock on the east side of the mountain. The only feldspar present is anorthite, and, because of this peculiarity, the western variety is here called *rougemontite*, and the intermediate variety, or essexite, is called the Rougemont type of essexite.

The ferromagnesian variety closely resembles *yamaskite*, a name given by G. A. Young[1] to a rock characterized by the great abundance of pyroxene, basaltic hornblende, and ilmenite, with only a very small percentage of anorthite; on account of the high content of olivine, the present variety is called olivine-yamaskite. The intrusions were brought to a close by sets of complementary dykes which are found cutting the country rock and also the magma itself. The contact in many places shows a development of breccia in which hornstone forms the fragments.

Yamaskite occupies, roughly speaking, the eastern half of the mountain. It is quite variable in mineralogical composition, showing all gradations from a nearly pure pyroxenite, but with some olivine and feldspar, through several combinations of these minerals with brown hornblende and biotite, finally going over to an essexite in which the feldspar is present in amount greater than 15 per cent. In texture also there is greater variation; it varies from very coarse to rather fine grain, and from porphyritic to even-granular.

Essexite in general occurs about the border of the yamaskite, and they grade into one another. It is distinguished from the latter

[1] Geol. and Petrog. of Mount Yamaska Que. Geol. Surv. Can., Ann. Rept., Vol. XVI, Pt. H, 1906.

by a higher percentage of feldspar, together with a more even, and, usually, finer grain.

Rougemontite. This is found in the western part of the mountain and is characterized by much finer grain and higher percentage of feldspar than the other types. It is more homogeneous than the others, and formed a later injection, but before the earlier part had fully solidified. This is brought out by the relations of apophyses of this type extending into the yamaskite and essexite. The greater part of the contact is hidden by the mantle of drift and vegetation which covers nearly the whole mountain, and could not be studied closely.

YAMASKITE.

This occupies the eastern half of the mountain. Since it was necessary to choose the specimens for analysis before detailed study of the thin sections could be carried out, those chosen were such as appeared in the field to best represent the various rock varieties as there noted, and to be of the freshest and best material. Thus the specimen selected to represent this type proves to be an olivine-yamaskite. The rock has a very dark, green-black colour; it is coarsely crystalline, and breaks with an uneven fracture. Well-bounded pyroxene crystals up to 2 cm in length are the chief constituents, but there is an abundance of a reddish olivine in irregular crystals ranging from 1·5 cm in length downwards. Small flakes of biotite occur at intervals, and small, white patches of feldspar give the only relief to the prevailing dark colour.

A study of the thin sections shows the presence of the following minerals arranged in the order of their formation: olivine, augite, brown hornblende, biotite, anorthite, black iron ore, and serpentine. No apatite is present. *Titaniferous augite* in stout crystals averaging 1·2 cm in length is the most abundant mineral present; it has irregular or rounded boundaries, but well developed cleavage and slight pleochroism as follows: **a** = purplish grey, **b** = grey to yellowish grey, **c** = pale brown. The absorption is **a** > **b** > **c** and the extinction $\mathbf{c} \wedge c$ reaches 37°. It occurs frequently intergrown with brown hornblende and biotite, and contains poikilitically small, rounded crystals of olivine. The purplish tinge is characteristic of the titaniferous variety of augite, and the optical orientation corresponds also with that mineral.

Olivine occurs in large, colourless crystals with an average length of about 1 cm, and in small individuals with a diameter of 1 mm All the crystals are rounded and are traversed by irregular cracks along which a greenish serpentine and iron ore have begun to form. A schiller structure is developed by the parallel arrangement of some brownish lath-shaped inclusions which occur in bunches and are too minute for determination. *Basaltic hornblende* frequently forms a narrow border to the augite individuals, and is often intergrown with the latter, shown by numbers of flakes of hornblende through the augite, which extinguish simultaneously. It is small in amount but is seen to have the same properties as the hornblende described in a subphase of this essexite. *Biotite* occurs in rather large individuals, and in small flakes. The larger crystals are usually found intergrown with the augite. The very strong pleochroism is as follows: **a** = light brownish yellow, **b** = **c** = dark reddish brown, the absorption is **c** = **b** > **a**.

Anorthite. The crystals of feldspar fill interspaces between the other minerals; the amount of the mineral is very small. Albite twinning is well developed, and some carlsbad twinning also, but many of the individuals show the result of strain in the bending of lamellæ and in uneven extinction. Zonary growth is visible in a few crystals. Measured by the method of Michel Levy, these feldspars prove to be anorthite; their character is more fully treated under Type No. 3. *Black iron ore* is seen to occur in irregular grains scattered through the rock: part, at least, is the result of the alteration of olivine.

The rock is holocrystalline, centimeter-grained, and equigranular for the most part. The crystals are multiform and irregular.

The minerals in this rock type were determined microscopically by the method of Rosiwald, to be present in the following relative proportions.

	% by vol.	Sp. gr.	% by wgt.
Anorthite	6·06	2·8	5·03
Augite	70·75	3·4	71·60
Olivine	13·38	3·3	13·15
Hornblende	8·82	3·4	9·02
Biotite	0·50	2·9	0·45
Iron ore	0·50	5·2	0·77
	100·01		100·02

From these calculated percentages of the various minerals, the specific gravity of the rock was calculated.

Calculated specific gravity........	3·37
Spec. grav. determined by weighing..	3·35
Difference	0·02

It is seen from the mode that the rock falls in the class of yamaskites; the high percentage of olivine must be noted, hence the name olivine-yamaskite. With increase of anorthite up to about 15 per cent we have the essexite type coming into prominence. This yamaskite differs from the original one described by G. A. Young,[1] from Mt. Yamaska, Que., in that in this case, augite preponderates over the brown hornblende, and there is abundant olivine present.

CHEMICAL ANALYSIS.

A chemical analysis of this rock was made by Mr. M. F. Connor of the Department of Mines, Ottawa, Canada. The following table gives this analysis contrasted with other similar types as noted.

	1	2	3
SiO_2	45·44	39·97	44·62
Al_2O_3	5·85	8·68	7·90
Fe_2O_3	2·84	8·63	4·22
FeO	6·49	7·99	5·67
MgO	16·24	10·32	14·00
CaO	18·16	15·18	19·44
Na_2O	1·03	1·19	1·20
K_2O	0·38	0·74	0·31
H_2O+	1·15	0·57	0·75
H_2O-	0·10		0·07
TiO_2	1·50	4·05	1·87
P_2C_5	....	0·10	.....
MnO	0·24	0·19	0·10
BaO	.....	.....	.....
CO_2	.....	.....	0·61
So_2	.....	1·15	.....
FeS_2	.....	1·01	.....
	99·42	99·77	100·75
S.G.	3·35		

1. Olivine-yamaskite, Rougemont. M. F. Connor, analyst.
2. Yamaskite, Mt. Yamaska, G. A. Young, analyst.
3. Essexite (Rougemont type), Rougemont, M. F. Connor, analyst.

[1] Op. Cit., p. 16.

According to the Quantitative Classification of Igneous Rocks, the yamaskite belongs to class 4, dofemane; order 1, hungarare, section 2, dopyric; rang 1, permirlic, section 3, calcinitic; subrang 3, magnesiferrous. This rock fills a gap in the tables of the classification and the name carolose is proposed; this name is derived from the Petite Caroline road which skirts the east base of the mountain in which the olivine-yamaskite is found.

VARIETY NO. 1 OF YAMASKITE.

This type is found in patches showing a gradation from yamaskite to an essexite-porphyry in which medium to large crystals of augite, and a few of olivine, occur as phenocrysts in a fine-grained groundmass made up of small laths of anorthite and small, irregular pieces of augite and olivine which have been broken off and separated from the larger crystals, and mixed with the feldspars. This occurs in many places throughout the yamaskite and essexite, near the southeast end of the mountain, but in too small amount in any case observed, to permit of separate mapping; a hand specimen of average size shows the change quite well.

Under the microscope the larger augite and olivine crystals show very irregular boundaries; pieces have evidently been split off and some may be seen just opposite the place from which they were removed; the rest are mixed with the feldspar laths. The augites often show schiller structure. Iron ore occurs through the slide in irregular grains, together with a few flakes of biotite and brown hornblende. The anorthite occupies most of the groundmass in short, stout prisms with irregular boundaries, and seldom exceeding 1 mm in length. A few of the larger crystals show bent lamellæ, the result of strain. Many small laths are enclosed by the augite.

VARIETY NO. 2. OF YAMASKITE.

This variety occurs near the southeast border of the igneous core, and is exposed on the cliff which forms the terminus of the igneous part of the mountain in this direction. It is associated with the variety just described, and occurs as coarse, pegmatitic nodules in a medium to coarse-grained matrix. The nodules range up to one foot in diameter and are composed chiefly of stout crystals of pyroxene $1\frac{1}{2}$ to 2 centimeters in length, with some olivine and anorthite. It appears to differ from the normal type mostly in coarseness of texture; the constituents are the same.

VARIETY NO. 3 OF YAMASKITE.

This variety is found in a ridge 200 feet long, 50 feet wide, and 10 feet high, surrounded by normal yamaskite. There is no exposure within a few feet, so that the field relations could not be definitely determined. The rock has a dark grey to black colour; it is even and fine grained, and is phanerocrystalline. Crystals of pryoxene and a few of olivine make up the rock; no feldspar is visible in the hand specimen.

Under the microscope this variety closely resembles the type described as olivine-yamaskite. The minerals present are the same, except that there is less hornblende, the real difference being in the texture, which is holocrystalline, and decimillimeter-grained, with a few larger crystals of augite and olivine. It is inequigranular, with multiform, irregular crystals which are consertal in arrangement, and seriate in size.

VARIETY NO. 4 OF YAMASKITE.

Occurs on the northeast face of the hill forming the highest part of the mountain, about 150 feet below the summit. This is within the borders of the main feldspathic type, and is the freshest part of an exposure which shows several varieties of the rock. It appears, then, to be a segregation. The difference from the olivine-yamaskite described above is merely one of texture; this subphase is millimeter-grained and inequigranular, with a multiform, seriate fabric. Olivine is abundant but subordinate to the augite; they together form about 90 per cent of the whole rock. The rest is made up of a small amount of anorthite and broken hornblende, and the products of decomposition —serpentine and iron ore from the olivine, and calcite from the pyroxene.

COMPARISON OF VARIETIES OF YAMASKITE.

Tabular Statement.

	Olivine.	Augite.	Anorthite.	Brown hornblende.	Grain.
Type......	Abundant.	Much.....	Very little	Abundant.	Medium to coarse.
No. 1.....	Abundant.	Abundant.	Much.....	Little.....	Fine and porphyritic.
No. 2.....	Abundant.	Much.....	Very little	Little.....	Very coarse.
No. 3.....	Abundant.	Much.....	Very little	Very little	Very fine.
No. 4.....	Abundant.	Much....	Very little	Little.....	Medium to fine.

ESSEXITE (ROUGEMONT TYPE).

This rock, which is intermediate between yamaskite and rougemontite, is found as a border facies of the yamaskite, and perhaps of the whole igneous mass, so far as it was possible to judge from the limited exposures. There is also a band running nearly north and south through the centre of the mountain, of uncertain width, separating the yamaskite from the feldspathic type. This appears to grade imperceptibly into essexite to the east, but the change to rougemontite on the west is more pronounced because of the decided difference in granularity, as well as in mineral composition. The detailed description of the type chosen for analysis is as follows:—

The rock has a dark grey colour; it is phanerocrystalline, medium-grained, with a few larger crystals of pyroxene. The minerals present are seen to be the following: augite in stout, well-formed crystals, a few of which reach 1·5 cm in length, but for the most part, it is in smaller individuals averaging about 3 mm. Olivine is next abundant of the dark constituents; it has a reddish brown colour, and the crystals are rather small, but evenly disseminated throughout the rock. Black iron ore is visible in a few grains. The white component is wholly feldspar in small crystals, and it is rather evenly distributed as a groundmass for the dark coloured minerals.

Under the microscope the minerals present are seen to be: black iron ore, anorthite, olivine, augite, and brown hornblende, stated in their order of crystallization. Calcite and serpentine are secondary products. The *iron ore* occurs in irregular masses and in small grains; the latter, at least, are the result of decomposition of the olivine. It is developed in fine lines in the pyroxene, forming a very dense schiller structure, in some instances.

Anorthite crystallized before the olivine, at least in part, as large crystals of the latter contain laths of the feldspar. The mineral occurs in stout laths averaging about 1 mm in length, but of irregular outline. It is bunched in the interspaces between the large crystals of augite and olivine, and penetrates their borders, or is completely enveloped poikilitically by them. It is altered in some cases to calcite and kaolin, but is mostly fresh. The properties are more fully described under Type No. 3.

Olivine occurs in large and small rounded crystals, traversed by irregular cracks, showing a slight alteration to serpentine and iron ore. A schiller structure is developed by bands of iron ore in dendritic forms, but with sharp outlines.

Titaniferous augite is seen to be present in stout, irregularly bounded prisms averaging 3 to 4 millimeters in length, and containing poikilitically, small laths of anorthite and rounded olivines. Cleavage is well developed and a slight pleochroism is apparent, as already described. Needle-like inclusions of iron ore in parallel arrangement give a schiller structure which becomes so dense in places as to considerably darken the mineral. Intergrowths with brown hornblende occur in some crystals. Calcite is scattered through some of the augites, and is arranged along cleavage lines. *Brown hornblende* occurs in a few cases intergrown with augite in mixed crystals. *Biotite* is very small in amount in this type, bordering the iron ore, and as minute flakes in the augite.

The texture of the rock is intermediate between the fine texture of type No. 3 and the coarse texture of No. 2 of the yamaskite. The mode is also intermediate, and there are all gradations from the one to the other. The presence of such a basic feldspar as anorthite, as the only representative of that class of minerals, is very unusual in essexites and for this reason the rock is here termed the rougemont type of essexite.

CHEMICAL ANALYSIS.

	1	2	3	4
SiO_2	44·62	49·96	43·91	43·66
Al_2O_3	7·90	18·83	19·63	17·35
Fe_2O_3	4·22	2·52	4·16	7·88
FeO	5·67	6·64	5·55	5·40
MgO	14·00	3·52	5·20	4·27
CaO	19·44	7·42	9·49	9·39
Na_2O	1·20	5·26	4·49	5·12
K_2O	0·31	2·58	1·51	2·07
H_2O+	0·75	0·07	} 0·53	......
H_2O	0·07	0·53		
TiO_2	1·87	2·40	3·80	1·21
P_2O_5		0·25	0·32	1·32
MnO	0·10	0·20	0·07	......
CO_2	0·60	..	0·51	......
FeS_2		....	0·64	..
	100·75	100·18	99·81	99·66

1. Essexite (Rougemont type) Rougemont mountain, M. F. Connor, analyst.
2. Essexite, St. Hilaire mountain. M. F. Connor, analyst.
3. Essexite, Yamaska mountain. G. A. Young, analyst.
4. Essexite. H. Rosenbusch, "Elemente der Gesteinlehre," p. 172, M. Dithrich, analyst.

According to the Quantitative Classification of Igneous Rocks, the essexite belongs to class 4, dofemane, order 1, hungarare, rang 1, permirlic, subrang 3. Magnesiferrous. This rock fills a gap in the scheme of classification.

It is seen from a comparison of the above analyses that the rougemont type differs from normal essexite in its high content of lime and magnesia, its low percentage of the alkalies, and of alumina.

The *mode* of this rock type is variable; it is intermediate between that of the olivine-yamaskite already described and that of the rougemontite, which will be explained later.

	No. 1.	No. 2.
Anorthite	5·03	45·75
Augite	71·60	34·54
Olivine	13·15	8·64
Hornblende	9·02	0·48
Biotite	0·45	......
Iron ore	0·77	10·58
	100·02	99·99

No. 1. Mode of olivine-yamaskite.
No. 2. Mode of rougemontite.

It is obvious from the mode that the rock falls into the class of essexites but is rather abnormal, as explained above in discussing the chemical composition.

VARIETIES OF ESSEXITE.

It will not be attempted to describe specimens showing the gradation from yamaskite through essexite to rouvillite, but under this heading will be treated certain variations in texture or in mineral composition, which include the presence in abundance of some mineral other than those normal to the type.

One variety is high in brown hornblende. It occurs in three or four places in the igneous exposure; most of the specimens came from the southeastern part of the mountain, but one is noted from the centre-top of the western face. This latter occurrence is finer grained and probably represents a border phase. The rock varies in texture, often showing a mixture of coarse and fine material in the same specimen; otherwise it does not differ markedly in appearance from the type of essexite and it would not be especially noted in the field.

Under the microscope the abundance of brown hornblende, biotite, and black iron ore, with the absence of olivine, are the prominent differences from the main type; the order of crystallization is the same, and the description of the minerals applies for both types, except that the feldspars show bent lamellæ as the result of strain. It will be only necessary then to describe the nature of the hornblende as follows:—

The *hornblende* occurs in large, irregular crystals 15 mm to 9 mm long, and in smaller individuals. It is frequently intergrown with augite and biotite, and encloses small laths of anorthite and numerous grains of black iron ore. The iron ore occurs in lines of small grains traversing the hornblende in different directions, and also in needles arranged parallel to one another to form a fine schiller structure similar to that noted in the augite. Pleochroism is strong, and as follows: **b** = dark reddish brown, **a** = pale yellowish brown to brownish yellow; **c** = orange brown. The absorption is **b**>**c**>**a**, and the extinction $\mathbf{c} \wedge c$ varies up to a maximum of 28°; many sections show 17° or less. It would appear then to be a variety of the basaltic hornblende with exceptionally high extinction angle. The pleochroism distinctly places it in this group, as shown by the accompanying table, but the variety which is recorded there with high angle of extinction does not resemble this mineral in pleochroism. The minerals for comparison were taken from Iddings' "Rock Minerals", page 351.

Comparison of Hornblende.

Variety	X = A	Y = B	Z = C	$Z \wedge c = C \wedge c$	Author.
Basaltic hornblende (Rougemont)	yellowish brown to brownish yellow	dark reddish brown	orange brown	28	
Basaltic hornblende (Bohemia)	pale brown	brown	dark brown	0–14	Levy and Lacroix
Kaersutite (Kaersut)	light brown	dark reddish brown.	darker reddish brown.	10	Ussing
Barkevikite (Norway)	light brownish yellow.	reddish brown.	deep brown.	0–14	Brögger
Basaltic hornblende (Wanyer Berg)	olive green	yellowish brown	greenish brown	37	Franzenan

ROUGEMONTITE: THE FELDSPATHIC TYPE.

This type of the Rougemont magma occupies the western half of the mountain; it is characterized by predominant anorthite, with pyroxene as the only important ferromagnesian mineral: its detailed description is as follows:—

The rock is phanerocrystalline, medium to fine grained, and has a medium grey colour. A slight fluidal arrangement of the constituents is usually apparent, giving a suggestion of gneissoid structure. A white feldspar is the predominant mineral and the dark constituents are: dark coloured augite, reddish brown olivine, and black iron ore; these are evenly distributed throughout the rock, and give it a mottled appearance when viewed at a short distance. The rock is very tough and breaks with uneven fracture

Under the microscope the minerals present are seen to be: iron ore, olivine, anorthite, augite, biotite and brown hornblende and secondary serpentine, in their order of crystallization.

The *iron ore* is black and occurs in irregular masses and in small grains, often surrounded by a narrow border of biotite. Most of it is primary but part of it is formed from the olivine. *Olivine* is present in small rounded crystals which are traversed by irregular cracks, along which a yellowish green serpentine has begun to develop. The olivine is quite subordinate in amount to the augite and is frequently found embedded in it. *Anorthite.* The feldspar crystallized later than the olivine but before the pyroxene, since small laths are found contained in the latter; it is the predominant mineral in the rock. The crystals vary in size, reaching 1 mm in length, and are not well bounded, because of mutual interference during crystallization, and of the effect of the previously formed minerals. Both albite and carlsbad twinning are well developed; the broad lamellæ and the stronger birefringence indicate a very basic plagioclase, and, measured by Michel Levy's method, it proves to be anorthite. An interesting verification is shown in some of those sections cut normal to (010); when the albite twins in one carlsbad half show equal illumination, the twinned albite lamellæ in the other carlsbad are both totally extinguished; this is a peculiarity of anorthite.

Titaniferous augite. Augite, next to feldspar, is the most abundant mineral in the rock; it occurs in irregular crystals up to 2 mm in length, and shows well-developed cleavage. A schiller structure is developed, at about 45° to the cleavage, by minute needles of some dark mineral; these are too small to identify. The augite has the purplish tinge characteristic of the titaniferous variety, and a slight pleochroism as noted in the olivine-yamaskite type; it is closely associated with the small amount of brown hornblende present, and contains crystals of iron ore, olivine, and anorthite.

Brown hornblende is very small in amount, and appears closely associated with the augite in such a way as to suggest that conditions were nearly right for its formation instead of the augite. It occurs in small, irregular patches and does not appear to be the result of alteration. The pleochroism has been noted in the ferromagnesian type.

Biotite is present in a few individuals, mostly as isolated patches between the other minerals, but these are arranged in groups with the same optical orientation showing them to be parts of the same crystals. It also occurs as a narrow border about some of the magnetite grains. The pleochroism is from a faint brownish yellow to a dark brown.

The rouvillite is holocrystalline, millimeter-grained, and inequigranular. It has a multiform, seriate, aphyric fabric, and the larger tabular feldspars have a subparallel arrangement.

CHEMICAL ANALYSIS.

The chemical composition of this rock is given in the first column of the following table.

	1	2	3	4
SiO_2	40·68	46·24	54·45	43·65
Al_2O_3	19·83	29·85	28·05	11·48
Fe_2O_3	4·68	1·30	0·45	6·32
FeO	6·49	2·12	......	8·00
MgO	7·67	2·41	......	7·92
CaO	17·64	16·24	9·68	14·00
Na_2O	1·10	1·98	6·25	2·28
K_2O	0·27	0·18	1·06	1·51
H_2O+	0·27	0·91	0·55	1·00
H_2O-	0·08			
TiO_2	2·04	....	....	4·00
P_2O_5	....	....	....	trace
MnO	0·10	....	....	trace
BaO	....	....	....	....
	100·85 S.G.3·14	100·35 S.G.2·85	100·49 S.G.2·69	100·16

1. Rougemontite, Rougemont mountain, Quebec.
2. Anorthosite, mouth of Seine river, western Ontario.
3. Anorthosite, fine-grained, almost white, Rawdon, Morin district, Quebec.
4. Essexite, Brandberg, Kirchspiel Crau, Norway.

According to the Quantitative Classification of Igneous Rocks, the rougemontite belongs to class 3, salfemane; order 5, gallare; rang 5, kedabekase.

The rock suggests a basic anorthosite in which the plagioclase is all anorthite; the content of ferromagnesian minerals is, however, too high to make the resemblance very close. On the other hand, an essexite is much lower in alumina, and higher in iron and magnesia than the rougemontite; the analysis cited is the one most closely resembling the latter. Rougemontite appears, then, to occupy an intermediate position but with alkalic relationships.

The following are the results of a calculation of the mode of rougemontite.

	% by vol.	Specific gravity	% by wgt.
Anorthite	52·25	2·8	45·75
Augite	32·51	3·4	34·54
Olivine	8·35	3·3	8·64
Iron ore	6·52	5·2	10·58
Hornblende	0·43	3·4	0·48
	100·04		99·99

From the mineral composition, the specific gravity of the rock was calculated as follows:—

Anorthite	45·75%	× 2·8	=	128·1
Augite	34·54	× 3·4	=	117·3
Olivine	8·64	× 3·3	=	28·6
Iron ore	10·58	× 5·2	=	55·0
Hornblende	0·48	× 3·4	=	1·6
	99·99			330·0

Calculated spec. grav	=	3·31
Determined by weighing	=	3·14
Difference	=	0·17

The specific gravities for the different minerals were assumed, hence there is some error there. The iron ore was all calculated as magnetite, which is probably not the case. The mode shows the peculiar character of this rock; no rock type has been noted before in which there is such a high percentage of anorthite as the only feldspar present, associated with such a high percentage of pyroxene with abundant olivine and iron ore; it is, therefore, proposed to call this rock type rougemontite, after the mountain in which it is found so abundantly.

CHARACTER OF DIFFERENTIATION IN ROUGEMONT MAGMA.

The differentiation in the Rougemont magma is very well shown by a comparison of the analyses of the three main types.

	1	2	3
SiO_2	45·44	44·62	40·68
Al_2O_3	5·85	7·90	19·83
Fe_2O_3	2·84	4·22	4·68
FeO	6·49	5·67	6·49
MgO	16·24	14·00	7·67
CaO	18·16	19·44	17·64
Na_2O	1·03	1·20	1·10
K_2O	0·38	0·31	0·27
H_2O	1·15	0·75	0·27
H_2O	0·10	0·07	0·08
TiO_2	1·50	1·87	2·04
P_2O_5			......
MnO	0·24	0·10	0·10
CO_2		0·60	......
	99·42	100·75	100·85

1. Olivine-yamaskite.
2. Essexite (Rougemont type).
3. Rougemontite.

The striking fact, seen at once, is that there is a decrease in silica with increase of feldspar. The high percentage of lime throughout is a notable feature.

DYKE ROCKS.

Among the dykes of Rougemont mountain are found the following types: *yamaskite*, *yamaskite-porphyry*, *essexite*, *camptonite*, and rocks showing a tendency towards *aplitic forms*.

YAMASKITE.

The yamaskite is essentially the same as that described for the main intrusion. It forms a 6 foot dyke in the essexite on the northeast face of the mountain.

The hand specimen shows a phanerocrystalline to cryptocrystalline rock with a dark grey colour. There are a few small phenocrysts of olivine and pyroxene visible, but the great mass of the crystals are too fine-grained to be easily distinguished.

Under the microscope the minerals present are seen to be: black iron ore, pyrite, olivine, augite, and anorthite. The iron and pyrite occur in small irregular masses and grains scattered through the rock; olivine in rounded crystals much subordinate in amount to the augite; the augite has a light grey colour and is not distinctly pleochroic; it has extinction $\mathbf{c} \wedge c$ about 43°. The anorthite crystallized last, in stout laths, often enclosing small augites. It is very small in amount.

The texture is inequigranular and the crystals are multiform, with averaging size of grain a little less than 1 mm, hence decimillimeter grained: they are seriate.

ESSEXITE.

This type occurs in a number of places in the coarse material in such a way that it could not be definitely decided whether it was merely a fine-grained phase of the latter or a true dyke; in a few places, however, it was possible to determine a definite relationship as that of dyke to country rock. The specimen to be described is from an 8 inch dyke cutting coarse yamaskite, near the southeast end of the mountain.

The rock is phanerocrystalline to cryptocrystalline with a dark brownish grey colour. A few crystals of augite with a length of 2 mm are visible and white feldspar can be distinguished in the dark groundmass.

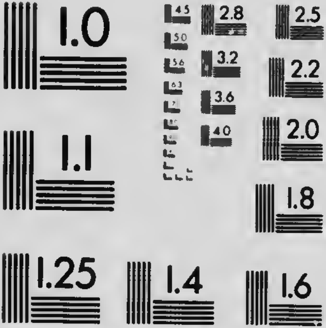
Under the microscope the rock is seen to have an ophitic texture, and differs mineralogically from the type essexite in that there is more brown hornblende present, with less olivine and less iron ore included in the pyroxene; otherwise the former description applies equally well here.

ESSEXITE PORPHYRY.

These dykes were found cutting coarse and fine essexite and also in the sedimentary collar. The largest found measured 2 feet 6 inches in width, and cut the hornstone about 1,000 feet from the southwest contact.

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



The smaller dykes and the contact facies of the larger ones show scattered phenocrysts of augite and olivine in an aphanitic groundmass; the texture is dopatic. The central part of the dyke becomes coarser and more abundant in phenocrysts, until in the centre of the large dyke cited above, the groundmass is holocrystalline, with a millimeter grain, containing phenocrysts of augite ranging from 1 to 2 centimeters in length. The rock has a dark grey colour and is given a greenish tinge by the amber-green, glassy olivines and the darker green pyroxene phenocrysts. The weathered portions show roughened surfaces where the pyroxene crystals are in relief; a newly broken surface of this portion shows spots of brown iron rust, where the olivine crystals have been decomposed, and also little nests of calcite crystals replacing some mineral, or filling cavities in the rock. Since the coarse variety approaches the normal essexite, only the finest porphyry will be described.

Under the microscope the minerals observed are: black iron ore, pyrite, olivine, augite, calcite, and decomposition products; no feldspar is visible, even with high power objectives, in the fine-grained portion. *Black iron ore* is abundant in small grains evenly distributed through the groundmass, and in phenocrysts 0·5 mm in length. *Pyrite* is in irregular grains about 0·1 mm in length, and included in all the phenocrysts, frequently surrounded by calcite in the replaced minerals. *Olivine* is found in small rounded crystals enclosed in augite, and in phenocrysts 2 mm in length by 1 mm in width, which show six-sided outlines, with rounded angles; it is highly decomposed. The products of decomposition of the olivine are: serpentine, black iron ore, talc, and chalcedony. The serpentine is greenish yellow and is found on either side of the cracks in the olivine. The iron ore is in little bunches, but usually in minute grains arranged in short, wavy lines throughout the crystals. Talc occurs in flakes and in radial growths within the crystal, and also forms a narrow margin about the whole crystal. It is colourless and has its usual high double refraction.

Augite occurs in well-bounded crystals up to 2 mm in length. Cleavage is well developed, and many of the individuals are twinned; some show zonary banding, and also an hour-glass structure. They contain a few crystals of olivine, but are relatively free from inclusions of iron ore. It has a light grey colour, but no apparent pleochroism, and its extinction $\mathbf{c} \wedge c$ is up to 40°. *Calcite* is present, filling many small irregular cavities throughout the rock, into many of which extend minute prisms of brown hornblende. It also forms part of the fine groundmass. *Brown hornblende* is recognizable only in the minute laths which extend into the cavities filled with calcite. The groundmass contains abundant brownish crystals which are too small to be determined, but are very probably hornblende also. The groundmass is very fine-grained, for the most part, an intimate mixture of brown hornblende, calcite, and black iron ore.

The rock is holocrystalline, porphyritic, and microcryptocrystalline in grain of groundmass, with millimeter-grained phenocrysts. It is dopatic (that is, the groundmass predominates), and the phenocrysts vary in size from minophyric to mediophyric and are prismoid in shape, with a skedophyric arrangement (scattered uniformly).

Chemical Analysis.

The following is the result of an analysis of an essexite porphyry dyke 1,000 feet southwest of the border of the essexite body.

SiO_2	44·39
Al_2O_3	8·36
Fe_2O_3	2·18
FeO	8·25
MgO	16·70
CaO	12·90
Na_2O	1·28
K_2O	1·28
TiO_2	1·98
H_2O −	0·02
H_2O +	2·08
MnO	0·15
	99·57

According to the Quantitative Classification of Igneous Rocks, the essexite porphyry belongs to class 4, dofemane, order 1, hungarare, section 5, pyreniare; rang 1, permirlic, section 2, domiric; subrang 2, domagnesic. This rock fills a gap in the classification tables.

CAMPTONITE.

Only a few true camptonites were found, and these with a width measured in inches rather than in feet. They occurred cutting the yamaskite and essexite. The description of this type is as follows:—

The rock has a dark grey colour; it is phanerocrystalline, but very fine-grained, with only a few small phenocrysts of augite and hornblende. Inclusions of the coarse country rock are seen in some places, in small fragments. Besides the scattered phenocrysts, small laths of feldspar and grains of pyrite can be readily distinguished, but not the dark minerals. In weathering, the rock takes on a brown spotted appearance, with cavities where some ferromagnesian phenocrysts have been dissolved out.

Under the microscope the following minerals are seen to be present, given in the order of their crystallization; garnet, iron ore, plagioclase, and hornblende. *Garnet* is a colourless mineral with high index of refraction, occurring in irregular to rounded grains about the hornblende crystals. It is traversed by irregular cracks and is isotropic. *Iron ore* is abundant in small grains throughout the rock and enclosed in all the other minerals. Most of it is pyrite, but some black iron ore is also present.

Plagioclase is the most abundant mineral present. It occurs in laths with an average length of less than 1 mm but a few are 2 mm long. Most of the crystals show well-developed twinning, both albite and carlsbad, and many of them exhibit a zonary structure. Measured by the method of Michel Levy, most of the feldspar proves to be labradorite $Ab_1 An_2$ to $Ab_3 An_7$; many of those crystals showing zonary structure have a core of bytownite, $Ab_1 An_4$ surrounded by a border of labradorite; but a few show a basic labradorite $Ab_3 An_7$ surrounded by the more acid $Ab_1 An_1$. *Apatite* is very abundant in some of the dykes, in long, slender prisms and in rounded grains. *Hornblende* is, next to the feldspar, the most abundant mineral, occurring in irregular crystals, few exceeding 1 mm in length. Many individuals are crowded with iron ore inclusions which often form reed-like masses arranged parallel to the cleavage, and also across it, giving a schiller structure. Where augite is present, the two are always intergrown. The pleochroism is very pronounced and shows **a** = very light brown, **b** = brown, **c** = brown. The absorption is **b** = **c** > **a** and its extinction **c** $\wedge$ c is observed to be 10° in the maximum seen, usually [illegible]°.

APLITIC DYKES.

These dykes show some very peculiar features; they were only found on the southeast end of the mountain and were not observed in relation to the other types except where one is cut by a 2 inch dyke of camptonite. Two varieties of this type occur, one where pyroxene is the only ferromagnesian mineral present, the other where there is considerable hornblende and biotite.

Aplitic Dykes: Variety No. 1.

Variety No. 1 occurs in a 12 inch dyke cutting essexite near the southeast edge of the mass. It is highly brecciated with fragments of the essexite in places, and is cut by a 2 inch camptonite dyke which also cuts the essexite.

The rock has a medium grey colour with a greenish tinge; it is phanerocrystalline, but very fine-grained, except for phenocrysts of pyroxene which are about 3 mm in length on the average, and have good crystal outline.

The minerals seen in thin section are: iron ore, apatite, pyroxene, plagioclase, and quartz, in their order of crystallization. *Black iron ore* and *pyrite* occur in irregular grains scattered through the rock. Pyrite is the more abundant. *Apatite* is not abundant; it is found in a few slender laths and in basal sections.

Pyroxene occurs scattered uniformly throughout the rock in small, irregular pieces averaging 0·1 mm in length, torn from larger crystals; a few well-bounded crystals are present up to 1 mm in length, also fragments of larger ones; but none of the larger phenocrysts are seen in the section examined. The larger pieces contain many gas cavities. The pyroxene has a light grey colour with no apparent pleoch[illegible]oism and an extinction angle **c** $\wedge$ c from 0° to 12°, frequently parallel, and maximum usually 6°—8°; the birefringence is about 0·013; it forms about 35 per cent of the whole rock. T[illegible]w extinction angle is very unusual in a pyroxene of this class and the low birefringence points toward the orthorhombic varieties.

The *plagioclase* is present in stout laths about 1 mm in length or less, with a few reaching as high as 2 mm; the outlines are not at all regular. Carlsbad twinning is very common and albite lamellæ are well developed, especially on the larger crystals. Measured by the method of Michel Levy, the feldspar is seen to vary from $Ab_3 An_7$ to $Ab_1 An_4$, with a preponderance of the latter; so that it is mostly bytownite, going over in cases toward labradorite. This mineral occupies about 40 per cent of the rock. Quartz was the last mineral to crystallize out and so occurs in the interspaces between the other minerals. It occupies about 10 per cent of the rock.

The rock is holocrystalline, inequigranular, with a hiatal, porphyritic fabric. It is perpatic and the phenocrysts are mediaphyric in size and prismoidal in shape; they are scattered, giving the rock a sedophyric texture.

Aplitic Dykes: Variety No. 2.

This occurs on the face of the hill at the southeast end of the mountain at the contact with the hornstone and its relations could not be made out, as to width and strike, but it cuts into coarse essexite. The hand specimen is aphanitic, dark grey in colour, and shows abundant scales of biotite, and some quartz; the other minerals cannot, as a rule, be distinguished.

The minerals present in thin section are seen to be: zircon, apatite, iron ore, plagioclase, augite, biotite, and quartz, listed in their order of crystallization. *Zircon* occurs in a few fine needles; *apatite* in a few slender laths; *black iron ore* in small, irregular grains scattered through the slide. *Plagioclase* occurs in short, stubby laths, for the most part, often enclosed poikilitically in the augite and biotite. It is also found in longer laths, about 0·3 mm in length, gathered in bunches in different parts of the rock. Carlsbad and albite twinning is common; and some crystals show microperthite intergrowth, with a tendency in cases to zonary banding. The feldspar is found to be mostly $Ab_1 An_4$ bytownite, but going up toward a labradorite. The *augite* is the same as that described in sub-variety No. 1 of the aplitic dykes. It occurs in irregular grains through the rock, seldom reaching 0·5 mm in length. *Biotite* occurs in large flakes 2 mm side, with irregular boundaries and often filled with minute feldspars, iron ore, and augite. It has a strong pleochroism from pale yellow to deep reddish brown. *Quartz* varies in amount; at times it forms the whole groundmass; it is probably derived, in part at least, from the nearby hornstone which is digested in it.

CHAPTER VII.

GENERAL PETROLOGY

In discussing this subject, St. Hilaire (Beloeil), and Rougemont mountains will be treated separately, and their relationship to the general Monteregian province shown as far as possible.

ST. HILAIRE (BELOEIL) ROCKS.

The igneous rocks of St. Hilaire mountain are characterized by a high content of soda, very high in some varieties. The main types represented are: essexite, rouvillite, nephelite-sodalite-syenite, and tawite.

The following analyses of these types were made by M. F. Connor:—

	1	2	3	4
SiO_2	49·96	51·26	54·74	41·84
Al_2O_3	18·83	23·78	21·53	28·42
Fe_2O_3	2·52	1·81	4·06	3·29
FeO	6·64	2·70	0·94	0·40
MgO	3·52	1·96	0·18	0·25
CaO	7·42	8·00	0·90	0·66
Na_2O	5·26	6·72	12·84	19·48
K_2O	2·58	2·16	4·18	2·06
H_2O+	0·07	0·55	0·35	0·14
H_2O-	0·53	0·10	trace	0·62
TiO_2	2·40	1·66	trace	0·00
P_2O_5	0·25	trace	trace	0·04
Cl	trace	......	......	4·47
MnO	0·20	0·10	0·14	0·15

1. Essexite.
2. Rouvillite.
3. Nephelite-sodalite-syenite.
4. Tawite.

Since these rocks represent two separate intrusions, they will be first compared as such, and then treated as a whole.

The rouvillite is a differentiate from the essexite, and analysis No. 2 shows that there is an increase of iron and magnesia; the mode of the rock shows that it is very feldspathic, and the chemical analysis resembles that of an anorthosite. The high content of lime and soda, and low percentage of iron and magnesia are more closely related to an alkalic anorthosite than to a theralite. The amount of rouvillite is relatively so small that the composition of the original essexite magma must have been approximately the same as that shown in analysis No. 1.

Similarly the tawite represented by analysis No. 4 is a product of differentiation from the nephelite-sodalite-syenite. The most noticeable points of difference are the increased percentages of alumina, soda, and chlorine, with a decrease in the silica and potash. The very high content of soda is unusual, and the abundant chlorine points to the presence of a large amount of sodalite. The original syenite-magma had a chemical composition very similar to that in analysis No. 3, since the amount of tawite is not sufficiently large to make much change in it.

The whole of these rocks from St. Hilaire mountain are related in their high content of soda. The syenitic types are characteristically different from those of the essexite, in their low percentage of lime, iron, and magnesia, with a higher content of alkalies. The intrusions here closely resemble those at Mount Royal, for in that area also an essexite mass was later intruded by nephelite-syenite.

ROUGEMONT ROCKS.

These rocks will be treated together since they are differentiates from one main intrusion. The rock-types represented are: yamaskite, essexite, and rougemontite; a comparison of the chemical composition of these types is given in the accompanying table:—

	1	2	3
SiO_2	45·44	44·62	40·68
Al_2O_3	5·85	7·90	19·83
Fe_2O_3	2·84	4·22	4·68
FeO	6·49	5·67	6·49
MgO	16·24	14·00	7·67
CaO	18·16	19·44	17·64
Na_2O	1·03	1·20	1·10
K_2O	0·38	0·31	0·27
H_2O+	1·15	0·75	0·27
H_2O-	0·13	0·07	0·08
TiO_2	1·50	1·87	2·04
CO_2	......	0·60	......
MnO	0·24	0·10	0·10
	99·42	100·75	100·85

1. Olivine-yamaskite, M. F. Connor, analyst.
2. Essexite (Rougemont type). M. F. Connor, analyst.
3. Rougemontite. M. F. Connor, analyst.

These rocks are marked by their high content of lime and magnesia. There is a decrease of (iron plus magnesia) with decrease of silica, from the yamaskite, through the essexite, to rouvillite. A comparison of the mineral composition of the two extremes of the differentiation shows:—

	1	3
Anorthite	5·03	45·75
Augite	71·60	34·54
Hornblende	9·20	0·49
Olivine	13·15	8·64
Biotite	0·45	......
Iron ore	0·75	10·58
	100·00	100·00

No. 1. Olivine-yamaskite.
No. 3. Rougemontite.
NOTE.—The essexite is intermediate between No. 1 and No. 2.

The change shown by this table is from a ferromagnesian rock to a feldspathic one, and the absence of brown hornblende in No. 3 is accompanied by a high content of iron ore.

Rougemont is more closely related to Mount Yamaska than to any of the other Monteregians. At Yamaska, however, the feldspathic differentiate of the magma is an akerite, and is much more acidic than the yamaskite, while at Rougemont the rougemontite is less acidic than the ferromagnesian rock.

GENERAL DISCUSSION.

It seems to be a general rule, that, in regions of alkalic rocks, the feldspathic varieties greatly preponderate over the ferromagnesian ones. An exception is found in the rocks of Gran, as described by Brogger[1], in which case the feldspathic varieties are very small in amount. As instances of those localities which follow the general

[1] Quart. Jour. Geol. Soc. London, Vol. 1, Feb., 1894.

rule, may be cited the Highwood mountains of Montana, as described by Pirsson,[1] the Province of Kola,[2] the Greenland occurrence,[3] and the Red Hill district of New Hampshire.[4]

In the Monteregian provinces, the amount of rock high in bisilicates is in all the mountains fully equal to, and in some of them greatly preponderant over, the quantity of syenitic material.

With this fact in mind, then, the suggestion arises to study the region surrounding the Monteregian province, with a view to ascertaining whether there are any facts which serve to explain the phenomenon. To the northwest there lies an enormous area of nephelite-syenites, and of anorthosites, of Pre-Cambrian age; and to the southwest, anorthosites occur over a large area in the Adirondacks. To the southeast and east there are the great masses of diabase and serpentine, known as the Serpentine Belt, which are of post-lower Devonian age and were intruded probably not long before the Monteregian magma, as will be shown later. As Dr. F. D. Adams pointed out,[5] the more easterly mountains contain proportionately more syenite and the western ones, a greater proportion of essexite. The syenitic types at Shefford and Brome mountains, which are the largest and most easterly of the series, are highly acidic, and the nordmarkite (of Dresser) even contain a little quartz. This general gradation from east to west would suggest a chemical relationship to the larger intrusions to the east which are so closely related to these in point of age.

It has already been pointed out that the rouvillite of St. Hilaire, and the rougemontite of Rougemont mountain, are very strikingly suggestive of a relationship to anorthosites in chemical composition, and both these rock types are differentiates from the typical essexite, as found at those places. The inference from these facts is, then, that the intrusive rocks of this whole region may have some relationship with one another and that the Monteregian provinces may form but one part of a much greater one.

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[1] Bull. 237, U. S. Geol. Surv., 1905, etc.
[2] Ramsay and Hackman, op. cit.
[3] Ussing, op. cit.
[4] Bayley, W. S., Bull. Geol. Soc. Am., Vol. 3, pp. 231-252.
[5] Jour. Geol., Vol. XI, No. 4, Apr.-May 1903, p. 251.

To cite analagous occurrences: Brögger has shown that the district of Gran is but a local demonstration of a much larger province, known as the Christiana province, which, taken as a whole, is highly feldspathic. Similarly, Pirsson has pointed out that the laccoliths and volcanic necks of central Montana form but the centre of a much larger province, in which the acidic representatives occur on the borders. So that it may well be that an exhaustive study of the region of western Quebec and the adjacent country will establish a similar major province in which the Monteregians are included.

DIFFERENTIATION.

It will not be attempted to discuss here the different hypotheses that have been advanced to explain differentiation, but the phenomena seen at St. Hilaire and Rougemont will be treated in relation to the conditions under which the process has operated in these instances. At St. Hilaire mountain, the feldspathic rock was intruded later than the ferromagnesian one, so that this differentiation must have been completed before the first intrusion took place. The rouvillite and tawite occurrences are, however, probably partly due to the local segregation of minerals contemporaneous with the intrusion of the differentiated magmas; their isolated occurrences and relatively small area would indicate that local conditions were operative in their formation, rather than a general cause.

At Rougemont the conditions show that there has been but one main intrusion, but that the feldspathic portion represents a slightly later phase in this intrusion than does the ferromagnesian rock. The latter is not at all homogeneous, but varies from a feldspathic essexite to a yamaskite which is made up almost entirely of bisilicates. No general separation of the two can be made in the field; the geological map shows, however, that exposures of the yamaskite occur irregularly throughout the mass, but the boundaries of each type are very indefinite. In this case, as at St. Hilaire, there was a differentiation before the intrusion took place, and a segregation contemporaneous with the intrusion served to accentuate the contrast between the two main products of differentiation, and to produce a third type intermediate to the extremes.

DYKES.

Each of the main intrusions at St. Hilaire mountain is represented in the dyke rocks; the intrusion of essexite was followed by dykes of camptonite, whose fine grain indicates that the wall-rock (essexite, in most cases) was cold at this time, or that there was a lack of mineralizers in the magma, or that both conditions were effective. There is also an aplitic sheet, in connexion with the essexite, which represents the extreme acid phase of differentiation in the residual magma. Accompanying, or following, the syenitic intrusion was a development of dykes of nephelite-syenite and tinguaite, together with a number of sheets of the latter. A small dyke of tinguaite cuts one of nephelite-syenite, showing that the former, at least, was later than the main syenite magma.

At Rougemont mountain there are representatives of both acid and basic phases of differentiation in the residual magma from which the dykes were produced; they range from yamaskites to acidic varieties containing some quartz which are described as aplitic types; the relative ages of these dykes were not definitely determined, since they were not observed in the same exposure.

It would seem, then, that the dykes represent a more complete differentiation in the original reservoir than is shown in the main intrusions; this would be expected because the differentiation in the residual magma would go on after the main intrusion occurred, and before the dykes were injected.

AGE OF THE INTRUSIONS.

There are a few facts which furnish a clue as to the general age of the Monteregian intrusions.

At Montreal there is a development of igneous breccia, in connexion with Mount Royal, in which there are entrapped blocks of limestone containing fossils of Oriskany age, so that the intrusion must have been post-lower Devonian. This is borne out by the fact that a dyke of a camptonite, from a small outlier of the Monteregian province, near Eastman, Quebec, cuts the serpentine of that region. The age of the serpentine is also considered to be post-lower Devonian.

Following a different line of evidence Dresser found that the igneous masses of both Shefford and Brome mountains show the effects of the regional disturbance which occurred at the close of the Appalachian revolution in Pennsylvanian-Permian time. It appears then that the Monteregian intrusions occurred some time between the lower Devonian and early Permian. It is very probable, however, that they took place in the upper Devonian which was a period of great volcanic activity in eastern North America.

CHAPTER VIII.

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CLASSIFIED LIST OF RECENT REPORTS OF GEOLOGICAL SURVEY.

Since 1910, reports issued by the Geological Survey have been called memoirs and have been numbered Memoir 1, Memoir 2, etc. Owing to delays incidental to the publishing of reports and their accompanying maps, not all of the reports have been called memoirs, and the memoirs have not been issued in the order of their assigned numbers, and, therefore, the following list has been prepared to prevent any misconceptions arising on this account.

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Report on the geological position and characteristics of the oil-shale deposits of Canada—by R. W. Ellis, No. 1107.

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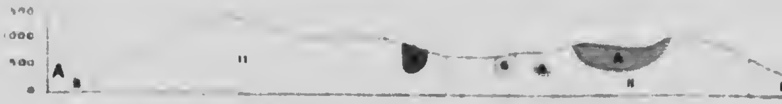
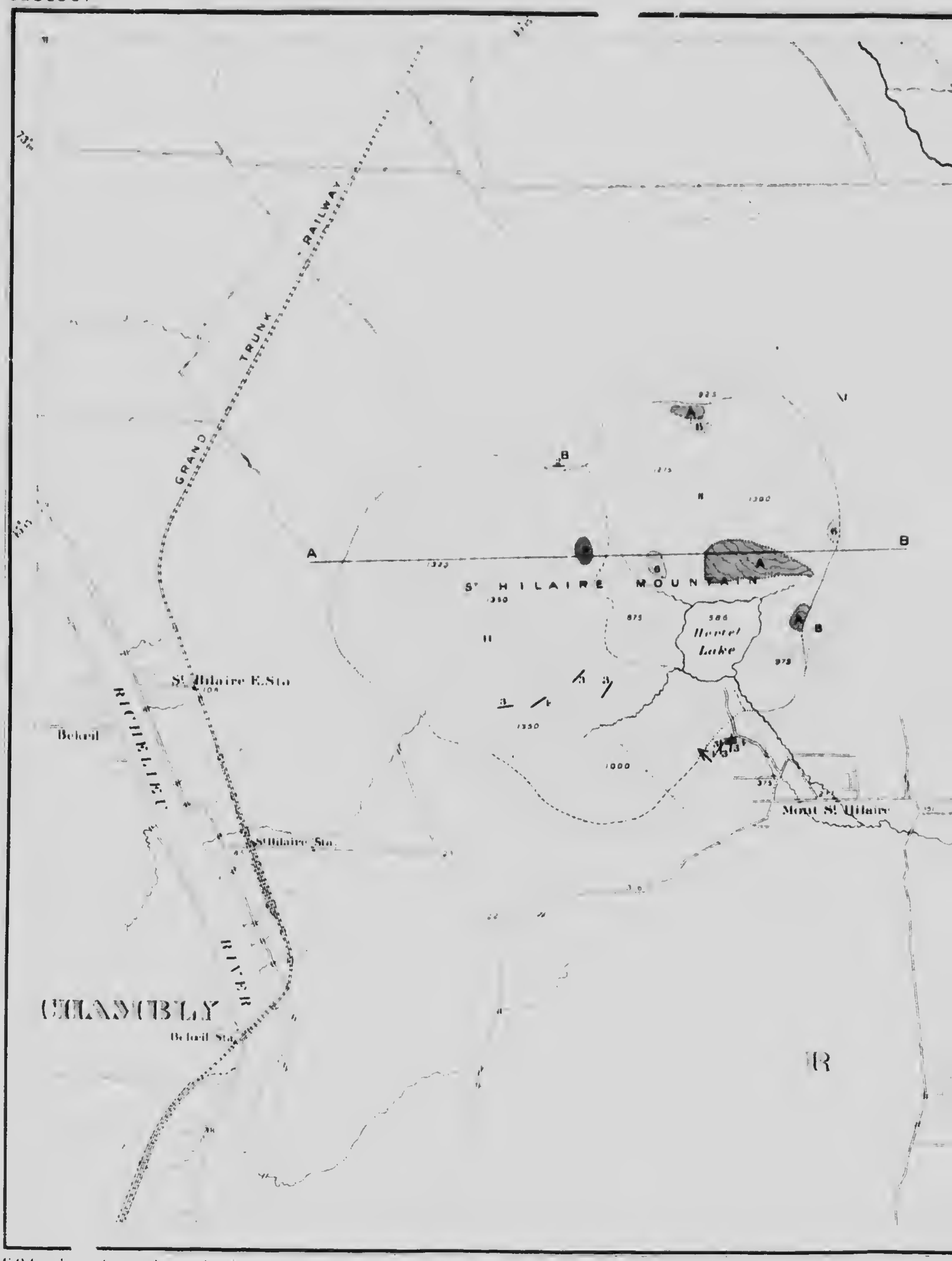


Structural section along line A B
Scale, horizontal and vertical, 2000 feet to 1 inch

GEOLOGY



LEGEND

Sedimentary

5
Hornstone

A
Limestone and marble

Igneous

11
Essexite

10
Rougemontite

9
Rouvillite

8
Nepheline-sodalite syenite

7
Yamaskite

6
Tawite

Dyke

Sheet

Symbols

Geological boundary
(position determined)

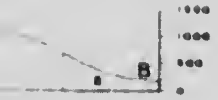
Geological boundary
(position approximate)

Geological boundary
(position assumed)

C.O.Senécal Geographer and Chief Draughtsman

To accompany Memoir by J.J.O'Neill

ST HILAIRE A



Canada

Department of Mines

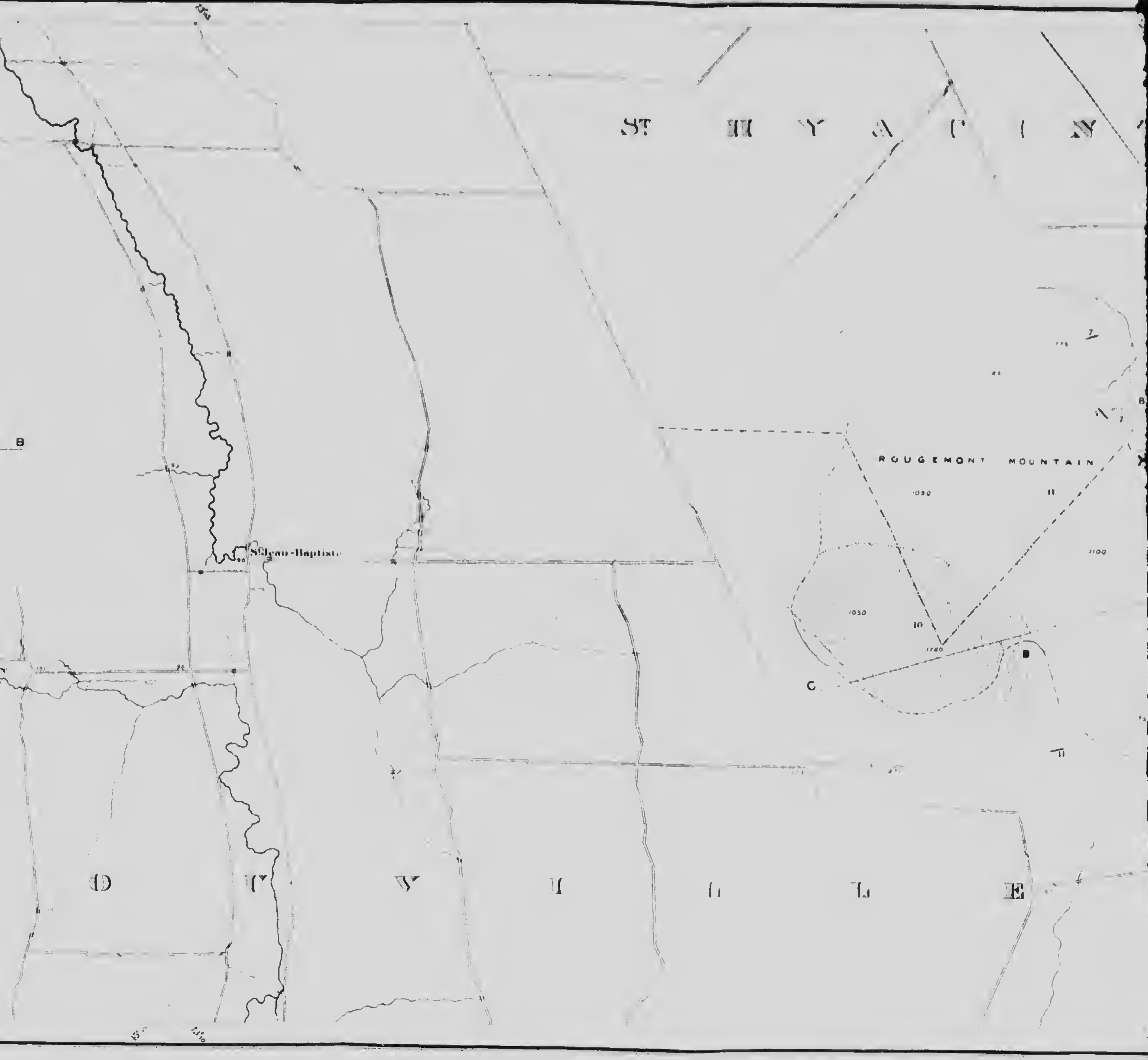
Hon. L. Coderre, Minister. A. P. Low, Deputy Minister.

GEOLOGICAL SURVEY

R. W. Brock, Director.

Structural section along line C D

Scale, horizontal and vertical 2000 feet to 1 inch



MAP 101A

(Issued 1914)

…RE AND ROUGEMONT MOUNTAINS, ROUVILLE AND ST. HYACINTHE COUNTIES, QUEBEC.

Scale of Miles

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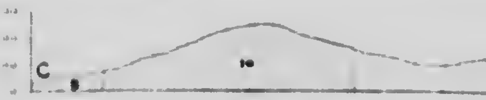
GEOLOGICAL SURVEY



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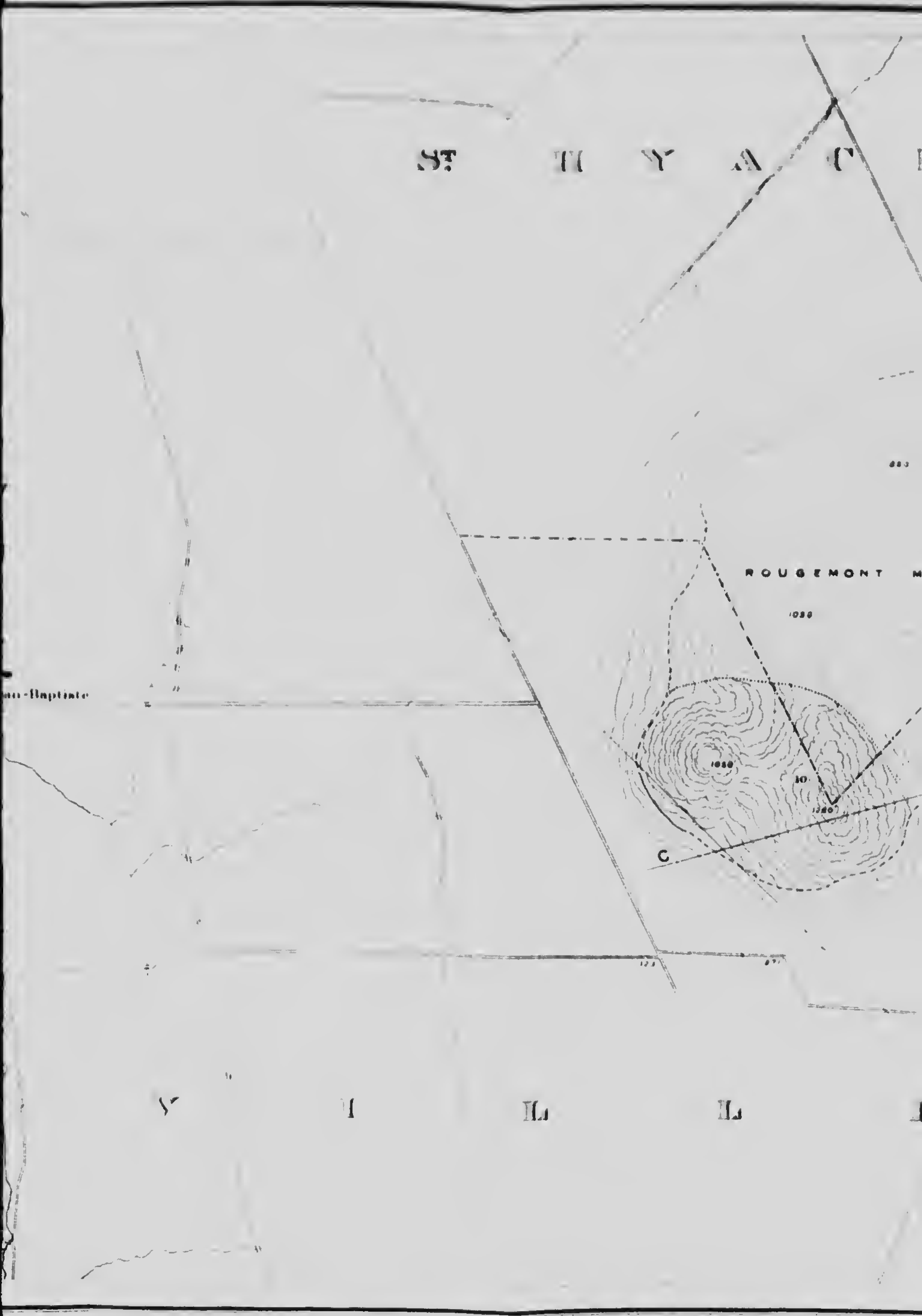

MAP 101A
(Issued 1914)

UNTAINS, ROUVILLE AND ST HYACINTHE COUNTIES, QUEBEC.

Scale of Miles

ection along line C D

OUTLINE MAP