NEPHELINE-SYENITES & PEGMATITES OF MOUNT ROYAL

THE NEPHELINE-SYENITES AND PEGMATITES
of
MOUNT ROYAL, MONTREAL, QUE.

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SUMMARY

(1). The igneous succession in Mount Royal is outlined emphasizing the fact that there were two distinct advances of a nepheline-syenite magma.

(2). The minerals forming the nepheline-syenites are enumerated and described.

(3). Those rocks which are definitely known to belong to the older nepheline-syenite and those known to belong to the younger are described separately.

(4). A number of types are described which belong either to the first or to the second intrusion but whose relations are not definitely known. These include most of the nepheline-syenite pegmatites, nordmarkite pegmatites, soda-rich monzonites, syenites and an unusual porphry intermediate between a shonkinite and an essexite.

(5). Seven analyses are given of the different rocks described.

INTRODUCTION

The volcanic neck or plug which forms Mount Royal presents a complex history of igneous activity. It comprises a varied and interesting group of rocks of plutonic and hypabyssal types, which penetrate gently dipping Ordovician strata.

In common with most of the other Monteregian Hills there were two main intrusions, a basic followed by a more alkaline magma. Dr. F.D.Adams[1] first pointed out the relations of these intrusions and described them and their associated dykes. The construction of a tunnel through Mount Royal has offered an unexcelled opportunity for study, and in a recent paper Dr. J.Austen Bancroft and W.V.Howard[2] have elaborated the igneous succession.

The sequence noted by these authors is as follows:-

(1). "By far the major portion of the igneous mass of Mount Royal is composed of essexite which represents the earliest intrusion in the area.

(2). The intrusion of the essexite was followed by a period of dyke injection. The oldest dykes within the area

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1. " The Monteregian Hills" by F.D.Adams. Guide Book No.3 12th International Geological Congress 1913.
   " The Monteregian Hills - A Canadian Petrographical Province by F.D.Adams. Journal of Geology, April 1903.

2. "The Essexites of Mount Royal, Montreal, Que." by J.Austen Bancroft and W.V.Howard. pp 14-15 Transactions Royal Society of Canada. Vol. XVII. 1923.

are bostonites, mica-tinguaites and tinguaite-porphyries, followed by camptonites and monchiquites.

(3). The essexite plug was then shattered and the body of older nepheline-syenite exposed in Corporation Quarry was then introduced. At the same time a large number of dykes and dykelets of nepheline-syenite traversed the whole body of essexite while a few dykes of nepheline-syenite porphyry were injected into the surrounding limestone for distances of at least a few hundred yards from the main igneous mass.

(4). Immediately subsequent to the advance of the older nepheline-syenite a vast number of dykes of camptonite, maenaite and other types were injected. Included in this group are dykes of several different ages.

(5). There then followed the extensive intrusion of camptonite that forms the matrix of the igneous breccia which underlies that portion of the second or western summit of Mount Royal beneath which the tunnel passes for over 600 feet (Stations 246+52 to 253+11). Here the essexite was not only shattered but in places was triturated by the camptonite magma. Fragments of the essexite, of the mica-tinguaite and tinguaite-porphyry of the older nepheline-syenite, similar to that exposed in the Corporation Quarry, and also of some of the dykes which were injected after this nepheline-syenite, have all been recognized in the camptomite matrix of this breccia.

(6). Numerous dykes of the more recent nepheline-syenite varying from a few inches to several feet in width were then

injected into the igneous complex of Mount Royal. In some instances these dykes grade from normal nepheline-syenite to pegmatitic and aplitic phases and it is believed that the coarse feldspar dykes, which in many places traverse the essexite, were intruded at this time.

(7). Then followed a closing period of dyke injection which gave rise to at least two types of camptonite dykes of different ages."

Each period of intrusion was followed by one of cooling and solidification and the above sequence provides a complex example of differentiation. This is especially striking where the two ages of nepheline-syenite are separated by an extremely basic camptonite, as illustrated by the matrix of the breccia.

The present paper is the result of a petrographical study of the nepheline-syenites and the allied soda rich rocks of the area, included in group (3) and group(6).

MINERALOGICAL COMPOSITION

Before describing these rocks an enumeration and short description of the minerals composing them will be given. The following have been observed:

PRIMARY

Orthoclase	Biotite	Fluorite
Plagioclase	Lepidomelane	Corundum
Nepheline	Muscovite	Pleonaste
Hornblende	Sphene	Astrophyllite
Aenigmatite	Garnet	Apatite
Augite	Zircon	Pyrite
Aegerine-augite	Nosean	Pyrrhotite
Aegerine	Sodalite	Black Iron Ore
Wollastonite		Calcite

SECONDARY

Kaolin	Natrolite	Rutile
Calcite	Sodalite	Selenite
Sericite	Analcite	Pyrite
Gieseckite	Hydronephelite	Hematite and Limonite
Cancrinite	Chlorite	Quartz
	Leucoxene	

Within the highly altered Trenton limestone, adjacent to some of the dykes that have been studied, the following minerals were present.

Calcite	Aegerine-augite	Orthoclase
Garnet	Augite	Plagioclase
Vesuvianite	Wollastonite	Nepheline
Diopside	White mica	Pyrite

Feldspars. Orthoclase is the dominant feldspar in these rocks. It shows the ordinary characteristics and has usually a strong tendency to elongation parallel to the clinopinacoid. The colour ranges from pale grey to pale salmon pink. Though the most prominent feldspar, it is invariably associated with plagioclase under more or less intimate conditions. Micro-perthitic intergrowths are very common and anorthoclase is abundant, especially in many of the aplitic and pegmatic phases. By refractive index and extinction angle determinations the plagioclase has been found to range from practically pure albite to Ab_{80} An_{20}, or intermediate oligoclase. In one unusual case which will be discussed later, the interior of zoned phenocrysts approaches labradorite, approximately Ab_1 An_1. The plagioclase usually developes somewhat better crystal outlines than the orthoclase and can be readily identified in the hand specimen by its blade or lath-like character. Albite and Carlsbad twinning are very common and pericline is not unusual. Mannebach is very unusual and has only been observed in one or two cases. Microcline is of rare occurrence.

Though the feldspars in samples taken from the tunnel are remarkably fresh, incipient alterations to kaolin, sericite and finely disseminated carbonate are frequently encountered. Near the surface alteration is further advanced although in some localities remarkably fresh examples can be obtained.

Nepheline. As Dr. Adams[1] has pointed out, this mineral is so abundant that the rock gelatinizes readily when powered and heated with dilute hydrochloric acid. The relative amount however is somewhat variable and its greatest development is seen in some of the aplites and pegmatites. Its colour is usually a dull grey with a greasy lustre, and less commonly it is flesh tinted and vitreous to greasy. The flesh tint is in part due to incipient alterations but perfectly fresh examples have been examined which also show this colour. By far the most common decomposition product is cancrinite, which has not been found as other than a secondary product. Sericite, sodalite, hydronephelite, analcite and a pale brown scaly mica, probably gieseckite[2] are others. Analyses[3] of the pinkish unaltered nepheline and of the analcite are given below.

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1. Guide Book No. 3, pp. 40.
2. Rosenbusch, Mikroskopische Physiographie, pp. 113.
3. On the Composition of Some Montreal Minerals. by B.J.Harrington Transactions of the Royal Society of Canada, 1906.

ANALYSES

	Nepheline	Analcite
SiO_2	44.98	54.83
Al_2O_3	32.65	24.20
Fe_2O_3	0.72	...
CaO	trace	0.08
MgO	...	...
Na_2O	16.08	12.01
K_2O	4.54	...
H_2O	0.97	8.50
	99.94	99.62

Amphiboles. The typical hornblende of these rocks shows fair crystal form, usually in elongated narrow prisms. Stouter prisms are also seen. The colour is very deep green or black. In thin sections the interior is often brownish while the margin is deep green. Opacite rims with the separation of dust like particles of magnetite, are common features. Pleochroism is fairly strong.

A hornblende presenting somewhat different characteristics is met with in a number of the dykes. Optically it is negative and the pleochroism ranges from X= yellowish green to Y=Z=deep bluish-green. The axial angle is small and the maximum extinction angle is 28°. A closer determination could not be made but the properties suggest hastingsite.

In several thin sections, a few small prismatic grains are found of a mineral which has been identified as aenigmatite. It possesses a good cleavage and an extinction angle of about 3°. The pleochroism is intense, brown-black to clear red-brown.

Pyroxenes. In thin sections the augite of these rocks may be almost colorless, or purplish and faintly pleochroic. More commonly it is very pale green with slight absorption. Aegerine-augite with similar characteristics and deep green, slightly pleochroic aegerine are also present, the latter being confined to the pegmatites. An analysis of the aegerine[1] is given below.

ANALYSIS OF AEGERINE

SiO_2	49.51
TiO_2	0.61
Al_2O_3	2.72
Fe_2O_3	22.26
FeO	5.82
MnO	1.51
MgO	1.09
CaO	7.16
Na_2O	8.62
K_2O	0.38
H_2O	0.57
	100.27

1. B.J.Harrington, Op. cit.

Where some of the pegmatites cut limestone, much lime has been absorbed. This has conbined with silica to form wollastonite. Though its source is undoubtedly extraneous to the magma it has crystallized from solution with the other constituents and in this sense must be regarded as primary. The crystals show good prismatic outlines, elongated parallel to the b axis, and the usual twinning and cleavages. The mineral also forms an important constituent of the contact metamorphic zone.

Micas. The micas are deep green or brown in colour, lepidomelane and biotite, and both are intensely pleochroic. Though generally very subordinate in amount to hornblende, the mica assumes a position of importance in some of the dykes. In a few instances it occurs to the exclusion of the hornblende. Primary white mica, probably muscovite, is rare. The composition of lepidomelane from a pegmatite in the Corporation Quarry is given below.

ANALYSIS OF LEPIDOMELANE[1]

SiO_2	32.96	MgO	0.73
TiO_2	2.80	Na_2O	0.98
Al_2O_3	10.34	K_2O	7.75
Fe_2O_3	8.85	Li_2O	0.03
FeO	27.19	F	none
MnO	2.79	H_2O	4.36
CaO	0.64	Total	99.42

1. B.J.Harrington, Op. cit.

Sphene. This mineral appears in all of these rocks. It is especially plentiful where the content of hornblende is high. Colourless crystals are most common, pale brown are rather rare and in only one case was a strongly pleochroic example seen, varying from yellowish-green to deep reddish brown. Alterations to calcite, opaque iron oxide, and calcite with reticulated groups of rutile needles are frequent.

Garnet. Though not invariably present, garnet is a very common accessory. The crystal habit is the dodecahedron though in one pegmatite, octahedral forms are abundant. Irregular shapes ranging up to two or even three millimetres in diameter are the general rule. The colour ranges from brown, through deep red-brown to black (melanite). Beneath the microscope lighter shades of brown are seen and a concentric zonal arrangement is at times developed. Minute inclusions of sphene, nosean, magnetite and plagioclase are often abundant. In one case an internal intergrowth or replacement by fluorite was observed in a relatively large dodecahedral crystal. Optical anomalies are infrequent.

Zircon. Though rarely of more than microscopic proportions, zircon is a very common accessory. In one of the pegmatites, however, crystals up to one and a half millimetres were observed. These had a pale yellow colour and were in bipyramidal forms. In thin section it is colourless but in a few cases it is of a very pale brown shade. Slight variations of this tint produce a concentric zonal banding. This is

particularly noticeable between crossed nicols when each successive zone is marked by a different vivid interference colour.

Nosean. Commonly confined to volcanic types this mineral is very abundant in some of these rocks. In thin sections it is colourless and shows rounded or hexagonal outlines. It is invariably filled with minute opaque inclusions which usually show a tendency to concentrate towards the centre of the crystals, but which are also concentrically or irregularly distributed. A zonal structure is sometimes seen.

Sodalite. Several relationships have been observed for this mineral. It ordinarily occurs as rounded or irregular grains, sometimes with a tendency to hexagonal outlines, forming a normal constituent of the rock. It is thus particularly well developed in the pegmatites. As a decomposition product of the nepheline it has already been mentioned. In one of the aplites it is found both as a normal constituent and as a filling of minute fissures. In this last case, movement evidently took place after almost complete solidification. The margin of the dyke, which is somewhat more basic than the interior, has been strongly sheared and in the closely spaced parallel fissures, sodalite and abundant pyrite have been deposited. Towards the centre of the dyke the minute cracks are very irregular and curving but are similarly filled. The sodalite was probably deposited by pneumatolytic agencies and the irregular character of the

interior cracks is interpreted as evidence of partial plasticity.

Because of its pale azure blue colour this mineral may be readily distinguished in the hand specimen. An analysis by Dr. Harrington[1] shows it to possess the following composition:

ANALYSIS OF SODALITE

SiO_2	37.52
Al_2O_3	31.38
Fe_2O_3	trace
CaO	0.35
MgO	trace
Na_2O	19.12
K_2O	0.78
Na	4.48
Cl	6.91
	100.54

Fluorite. Deep purple fluorite is not of frequent occurrence though in some of the pegmatites it is rather abundant. In thin sections it invariably presents anhedral forms and though generally colourless it sometimes shows patches of a deep bluish violet colour.

Corundum. This mineral was identified in a hand specimen taken from a dyke of the later nepheline-syenite (Tunnel Station 251-66). It occurs as grains and crystals so small that they can only be distinguished under the microscope, constituting nevertheless almost five per.cent. of the rock. A few

1. "Notes on a few Canadian Minerals and Rocks" by B.J. Harrington. (Extract from the Report of the Can. Geo. Survey. 1874-1875.

hexagonal and tapering sections are seen but anhedral grains are far more common. It is colourless but in some cases shows irregularly distributed zones which are distinctly blue and pleochroic, bluish to colourless. Optically it is uniaxial and negative.

Corundum has not been previously identified on Mount Royal or in fact within the Monteregian Petrographical Province. It is then of especial interest to find that even so local a portion of the magma as a single dyke was supersaturated with alumina. Further interest is attached in that the appearance of this mineral connects these rocks, petrographically at least, with the far more spectacular development of corundum-syenites in the Haliburton and Bancroft areas of south eastern Ontario[1].

Pleonaste. The occurrence of this mineral is restricted to a dyke of later nepheline-syenite porphyry, a half an inch in width, (Tunnel Station 246+25) within which it is disseminated as abundant small irregular grains.

Astrophyllite. Small grains of a mineral showing the characteristic cleavage and pleochroism of astrophyllite have been observed embedded in fluorite.

Calcite. In samples of dykes taken from the very core of the mountain, and unaltered in every respect, calcite is found

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1. Geology of the Haliburton and Bancroft Areas, Ontario. by F.D.Adams and A.E.Barlow. Mem. 6. G.S.C. 1910. Rept., Bureau of Mines, Toronto, Ont. Vol. 8 pt. 2, 1899. by W.G.Miller.

in clear interstitial forms. Such occurrences force the conclusion that it is primary.

Apatite, pyrrhotite and black iron ore present their usual characteristics and occur as minor accessories, The last is frequently titaniferous and is partially decomposed to leucoxene.

Further mention of the secondary minerals does not seem necessary at this point. The occurrence of gypsum in drusy pegmatites is of especial interest and will be discussed later.

The contact metamorphic zones have been described in a previous paper[1] and nothing can be added as to the characteristics of the minerals or their paragenesis. It is noticeable however that the normal nepheline-syenite dykes have little effect on the limestone while even the smallest of the pegmatites produce very pronounced contact metamorphic effects.

OCCURRENCE AND CHARACTERISTICS.

The Older Nepheline-syenite.

The main intrusion of nepheline-syenite occurs on the north-west slopes of the mountain. It is irregular in outline and occupies an area of about a half a square mile. Good exposures are abundant and the almost vertical contact with the Trenton limestone to the north is well exposed in the Corporation Quarry. Along the southern contact, where the rock intrudes essexite, a breccia is frequently developed, the matrix of which

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1. "The Contact Metamorphic Zone of Mount Royal, Montreal, Que". by E.P.Dolan. Trans. of the Royal Soc. of Can. 1923.

is the normal nepheline-syenite and the inclusions are commonly of the pyroxenite phase of the essexite[1]. The fragments are seen in every state of preservation from large blocks several feet in diameter to triturated crystals. This breccia is very perfectly exposed in the vicinity of the small pond in the Catholic Cemetery, where the rock exposures are smooth and polished by glacial action and the thin mantle of drift has only recently been removed. Here the fragments occupy more space than the matrix and both are cut by small stringers of nepheline-syenite aplite, which in turn are traversed by camptonite dykes.

The older nepheline-syenite shows remarkably little variation. It is grey or more rarely pinkish in colour, medium grained, and possesses a hypidiomorphic texture. It is composed essentially of orthoclase, nepheline and hornblende with albite, augite, aegerine-augite, biotite, sphene, garnet, zircon, sodalite and other minerals as accessories. Nosean is a characteristically abundant accessory and though it is sometimes found in the younger nepheline-syenite it is never so plentiful. A porphyritic appearance is occasionally developed due to the presence of larger hornblende and augite crystals having maximum dimensions of about a centimetre. This phase may be seen four hundred feet east of the Corporation Quarry. At some of the contacts a tendency to flow structure is observed, as evidenced by the horizontal alignment of the individual grains.

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1. J.A.Bancroft and W.V.Howard, opus. cit.

On the only detailed map[1] of the area seven other small bodies are shown. In some cases these represent areas in which there are very numerous dykes of nepheline-syenite and in which the mapping has been somewhat generalized. These show such a similar composition and appearance to the main mass that they are believed to have been intruded at the same time. The three small masses outcropping near the "Lookout", in the vicinity of the baked collar of Utica shale, are so deeply decomposed that no definite determination can be made.

In the construction of the tunnel numerous dykes of nepheline-syenite were encountered. Where these, through intersections with dykes of known age, can be definitely assigned to the older nepheline-syenite they show characteristics identical to it, although usually somewhat finer grained. To this only two exceptions have been noted. In a few dykes albite assumes a position of equal or greater importance than orthoclase, though no other points of difference arise. Finally, to the north of the main nepheline-syenite mass, at least four dykes of nepheline-syenite-porphyry have been injected into the limestone for distances of several hundred yards or more. Their outcrop has not been discovered and they are exposed only in the tunnel. These porphyries are a little darker grey than the normal nepheline-syenite and contain more abundant nosean than has been observed in any other type. The phenocrysts are prominent, up to four millimetres in diameter, and consist of plagioclase, orthoclase

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1. Accompanying Guide Book 3. Mapping by J.J.Stansfield.

and nepheline, the plagioclase being zoned from intermediate oligoclase to albite. The dark minerals show poorer idiomorphic outlines and include augite, hornblende and biotite together making up from one eighth to one fifth of the rock. These are set in a fine grained groundmass consisting of irregularly disposed small laths of orthoclase and albite with abundant interstitial nepheline. Sphene, magnetite, pyrite, apatite and in one case melanite, are accessories.

The Younger Nepheline-syenites.

Previous to the construction of the tunnel a second distinct advance of the nepheline-syenite magma had not been recognised. It is true that aplitic and pegmatitic dykes [1] had been commented upon but these were merely considered to mark the final phase of a single period. As the heading advanced into the camptonite breccia, however incontrovertible evidence became available that this was not the case. The breccia contains besides fragments of other older rocks, abundant inclusions of older nepheline-syenite. These are identical to the nepheline-syenite of the main mass, from which they were undoubtedly derived, and vary in size from large blocks to minutely triturated grains. The breccia with its included fragments of the older nepheline-syenite, is traversed by numerous dykes and abundant dykelets of a younger nepheline-syenite. The small monzonite stock of Mount Royal Heights. which though of similar character and relationships, has been modified

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1. F.D.Adams, Guide Book 3. p. 45.

by its absorption of siliceous and calcareous inclusions, can probably be assigned to this period[1].

Mineralogically, the typical younger nepheline-syenite shows little or no difference from the older, and indeed it is difficult to give a description which would serve as an infallible guide in distinguishing the two. To the trained observer in this area there are, however, certain features upon which a classification can be made with some degree of certainty, even where field relations are obscure. It is somewhat finer grained than even the older nepheline-syenite dykes, and distinctly finer grained than the main intrusion. Moreover it is usually a little lighter grey in colour. The most characteristic feature which it exhibits is a strong tendency to differentiate towards aplitic and pegmatitic types and it is also represented by homogeneous aplites and pegmatites. In those types intermediate between the aplite and the nepheline-syenite, biotite is apt to be the dominant dark mineral and in some cases completely displaces hornblende.

The aplites are found in profusion cutting the camptonite breccia. The typical example is pinkish in colour, medium-grained and distinctly granular. In thin section it is seen to be almost entirely composed of orthoclase, nepheline and plagioclase, in decreasing order of importance, all of which are

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1. "Absorption of Inclusions of Potsdam Sandstone by an Alkalic Magma, Mount Royal Heights, Montreal". by R.A.Pelletier, 1924.

at times intergrown. In addition there are a very few and usually small fragmentary individual grains of strongly pleochroic hornblende, a few ragged individuals or aggregates of small flakes of biotite, one or two irregular dusty grains of nosean, and widely disseminated small grains of magnetite, pyrite and sphene. Occasionally melanite, aegerine-augite or augite, sodalite and fluorite may be present.

These aplites are by no means confined to the breccia, but have been intersected elsewhere in the tunnel and are also well exposed cutting the older nepheline-syenite in the vicinity of the Corporation Quarry. In this last case they could possibly be assigned to the final period of consolidation of the older intrusion, were it not for the following significant facts. Similar petrographical types are known to cut the camptonite breccia and to be closely associated with the younger nepheline-syenite. They are in no sense aplitic segregations of the main mass, such as are so often found in large areas of granitic rocks, but occur in well defined dykes cutting it. Finally though fragments of the older nepheline-syenite are so abundant in the camptonite breccia, no aplite fragments have been found.

Though many of the aplites show a tendency towards pegmatitic phases, especially in the Corporation Quarry, only one sample of a pegmatite has been examined which cuts the camptonite breccia and is therefore definitely to be assigned to the younger nepheline-syenite (Tunnel Station 252+84).

A number of smaller occurrences, however, are recorded in the field notes, emphasizing similar characteristics. This rock is coarse grained, with crystals having diameters up to one half inch, and is composed almost entirely of feldspar and nepheline, in about equal amounts, together with a very few rather large flakes of black mica and rather abundant purple grains of fluorite. A number of drusy cavities are present and in these calcite has been deposited together with projecting acicular crystals of natrolite. The rock has a curious mottled appearance due to the sharp contrast of the white feldspar and the flesh colored nepheline. In the thin section a very few small sphenes and minute zircons are observed and the feldspar is seen to be albite with subordinate orthoclase. In the interstices between some of the larger feldspar crystals or gathered in small groups in the nepheline are found small, irregularly disposed albite laths. The mica is intensely pleochroic lepidomelane, somewhat altered around its margin and along cleavage cracks to little grains of magnetite. Finely disseminated pyrite and a little secondary cancrinite and sericite are present. The twinning laminae of the albite are bent in many cases and strain shadows are prominent. Evidently the rock has undergone considerable pressure though no cataclastic structure has developed.

Of rock types which are definitely known to represent the younger nepheline-syenite, only the porphyries remain.

These are almost as restricted in their occurrence as those belonging to the older period. They show, however more diversity than the older nepheline-syenite porphyries, reflecting the strong tendency of the second intrusion to differentiate into somewhat varied types.

The most prominently porphyritic dyke cuts the camptonite breccia at Tunnel Station 248+83, and in the hand specimen greatly resembles the older porphyries. In thin sections however, several points of difference arise. Nosean is completely absent instead of being abundant, the groundmass is granular rather than lath-like and orthoclase does not occur in phenocrysts. The most pronounced phenocrysts are tabular crystals of nepheline, in some cases showing the characteristic overlapping or shingle structure and subordinate to these are plagioclase crystals zoned from intermediate oligoclase to albite. Prisms of hornblende are rather abundant and are largely altered to pale green chlorite with the separation of little grains of pyrite. Pale green augite, fringed or altered along cracks to a similar chlorite, is a lesser constituent. There are a number of small altered sphenes and the granular groundmass is composed of orthoclase, abundant nepheline and a little albite. Through this are disseminated grains of pyrite, a little magnetite, and much sericite, finely diffused calcite, and secondary cancrinite.

A somewhat more acidic and finer grained phase is found at Tunnel Station 246-25. Here the breccia is cut by innumerable irregular little dykes and stringers. In thin section

one of these was found to contain phenocrysts of orthoclase and oligoclase, in about equal proportions, and very small disseminated flakes of strongly pleochroic brown biotite. These are set in a fine grained, granular groundmass of orthoclase and nepheline. Irregular grains of pleonaste, a few minute zircons and rounded grains of magnetite and pyrite are accessories. Small irregular areas of calcite, a little sericite and a few small radiating groups of needle-like crystals of natrolite are present as decomposition products. The rock is very pale grey in colour and the phenocrysts attain a fairly uniform length of about two millimetres.

In a few cases thin sections reveal a tendency to porphyritic structure which is not observable in hand specimens. This is well illustrated in a sample from Tunnel Station 252+71. The rock is characterized by very abundant grains of nepheline together with those of orthoclase and albite. All three are equigranular, exhibit a tendency to idiomorphic outlines, and are, in part, micrographically intergrown. In the interstices between them are closely packed small hypidiomorphic grains of the same minerals. Biotite, in small flakes or in aggregates of small flakes, is sparsely disseminated through the rock. Zircon, sphene, a little dusty nosean, a very little sodalite, one or two anhedral grains of fluorite and disseminated grains of pyrite and magnetite are accessories. It is a nepheline-syenite very low in mafic constituents.

Summary of the Two Ages of Nepheline-syenite.

The presentation of the above facts can leave no doubt as to the advance of two distinct nepheline-syenite magmas, and their existance and recognition is probably the most important contribution of this paper. The first and major intrusion is a nepheline-syenite of generally uniform character with relatively few textural or mineralogical variations, while the second, though in some cases very similar, is largely represented by less mafic types. Together with the intervening basic intrusion of camptonite they add still further to the already complex problems of differentiation in the area.

Regarded broadly the Monteregian Hills show major basic intrusions followed by more acidic alkalic magmas. The repeated pulsation from basic to acidic magmas is illustrated by Mount Royal. It is not the purpose here to discuss this differentiation, which is a problem falling outside of the scope of this paper. It is desired however to emphasize the fact that the igneous sequence in Mount Royal does not illustrate increasing acidity, but rather successive advances of basic magma each followed in turn by an advance of acidic magma.

Types Associated with First or Second Period.

Number of distinct rock types have been examined whose age is not made evident by field relations. These are undoubtedly to be assigned either to the older or the younger nepheline-syenite

and in some cases indirect evidence favours their association with one or the other. It seems preferable however to describe them separately pending more definite information.

Pegmatites. Foremost amongst these are the pegmatites found between the main essexite contact and Tunnel Station 191+33. They intersect uncorrelated camptonite dykes and are intruded into Trenton limestone. The grain is coarse, individual crystals attaining diameters, of two centimetres or more with an average of about one centimetre, and the colour is white or pale grey. Exclusive of nosean, pleonaste and corundum, all the minerals previously mentioned and described are at times present. Orthoclase and nepheline are essential constituents and the former nearly always shows microperthitic intergrowths. Albite is invariably present in long narrow prisms, anorthoclase is of very general occurrence and occasionally graphic intergrowths between albite and orthoclase are seen. Lepidomelane, hornblende and the pyroxenes may be sparsely distributed or may be completely absent. Fluorite and sodalite, though not invariably present, here reach their greatest development and melanite may be locally abundant. With the exception of sphene and zircon, other accessory minerals are not much in evidence. The proportion of nepheline present varies greatly in different dykes, this mineral usually being of a dull grey colour, more rarely, of a pinkish tint.

These nepheline-syenite pegmatites form well defined dykes up to eight inches wide and also occur as irregular dyke-like

injections. In one case (Tunnel Station 194+50) a granular nepheline-syenite dyke is braided with irregular pegmatitic segregations. The nepheline-syenite is of the normal type except that the mafic constituents are represented only by aegerine-augite intergrown with an occasional flake of biotite.

The contact metamorphic effects upon the limestone have already been mentioned and in addition fragments of limestone are sometimes included giving rise to beautiful crystals of vesuvianite. In one instance (Tunnel Station 193+35) the pegmatite is literally banded with inclusions of white crystalline limestone holding a few vesuvianite crystals. On being struck with a hammer it gives off a most unpleasant stench not unlike that of the old fashioned sulphur match. When examined under the microscope the individual calcite grains are often seen to contain little brownish patches of a material which is believed to be of organic origin, and to it the stench is attributed.

Nordmarkite Pegmatites. A number of coarse feldspar pegmatites cut the essexite as dykes up to three or four feet wide. More often however, they are extremely irregular, pinching and swelling and following tortuous courses through the essexite. A somewhat similar association with nepheline-syenite pegmatites has been noted in eastern Ontario[1].

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1. The Nepheline and Associated Alkalic Syenites of Eastern Ontario. by F.D.Adams and A.E.Barlow, Trans. Royal Soc. of Can. 1909. p.46

These pegmatites are coarse grained rocks, the feldspar often attaining diameters of an inch or more. Drusy cavities are abundant. In colour, they vary from a pale to a deep salmon pink. Coarse interlocking crystals of orthoclase form the greater part of the rock and dull green earthly masses of chloritic material with calcite represent some altered ferro-magnesian constituent which was present in subordinate amount. With the microscope, remnants of biotite or augite together with an occaisonal highly altered sphene and a little black iron ore can be detected. The orthoclase is perthitically intergrown, anorthoclase is present and a few small prismatic crystals of albite are included in the larger individuals of orthoclase. Into the cavities, orthoclase crystals have grown freely and are coated, and in part replaced, with quartz, calcite, gypsum and pyrite. Acicular crystals of natrolite project into the cavities and this mineral often forms more massive incrustations. The gypsum is of the variety selinite and is frequently found in large crystals three or four inches across. It is colourless and transparent and is associated with quartz and with coarsely crystalline, yellowish or pale blue calcite. Some doubt is felt as to the origin of the gypsum. The present underground waters are of a dominantly sodium carbonate type, though within certain restricted areas calcium sulphate and other saline waters occur. C.L.Cumming considers that the salts possibly originated at the time of the volcanic eruption of Mount Royal[1]. It seems probable

1. The Artesian Wells of Montreal, by C.L.Cumming. G.S.C. Memoir 72. pp. 5-11.

that the gypsum was formed through the agency of acid volcanic waters directly connected with these dykes, for it is significant that gypsum is not found with other rocks of the area. It might be pointed out that the drusy character of these pegmatites lends itself to the circulation of solutions of meteoric origin. On the other hand equally porous nepheline-syenite pegmatites or the shattered rocks of the contact are completely barren of selenite.

This rock has been classified as a nordmarkite pegmatite. A complete analysis (Analysis D)[1] has been made but for purposes of comparison a partial analysis is shown with two others of nordmarkite from different localities.

	I.	II.	III.
SiO_2	63.20	61.77	68.04
Al_2O_3	18.94	18.05	17.92
Fe_2O_3	0.27	1.77	0.96
FeO	1.00	1.75	2.08
MgO	0.38	0.89	0.59
CaO	1.50	1.54	1.00
Na_2O	5.84	6.83	6.67
K_2O	7.56	5.21	6.08
H_2O	0.11	1.10	1.18

I. Nordmarkite-pegmatite, Montreal, Que. M.F.Connor.

II. Nordmarkite, Brome Mountain, Que.

III. Nordmarkite, Tonsenas, near Christiana, Norway.

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1. Analyses will be found at the end of this paper.

A feature observed in a number of these dykes is a marginal phase of very different composition and texture. It is a rock of medium grain, equigranular and dark grey in colour. Examined in thin section it is found to consist of tabular crystals of orthoclase and oligoclase in about equal proportions, abundant elongated and often irregular prisms of hornblende with green margins and brown interiors, prisms or irregular forms of pale green augite, and a few flakes of biotite intergrown with the hornblende. Abundant sphene, titaniferous iron ore and apatite are present as accessories. The rock is very fresh but a little finely diffused calcite and sericite are present. It has been classed as an alkali-monzonite.

Though small stringers of the nordmarkite-pegmatite interior cut the monzonite margin, the phenomena can in no sense be interpreted as the intrusion of a younger dyke along the line of weakness in the older. Rather it indicates an excess of mineralizers and an acidifying of the magma either through marginal segregation or through differentiation at depth. The latter case seems the most probable in view of the sharp contacts between the two types.

Soda-rich Monzonite. A somewhat similar soda-rich monzonite is found at Tunnel Station 229+05 where it forms a well defined dyke three feet wide. It is medium grained and on first appearance it very much resembles the older nepheline-syenite, though darker grey in colour. Upon a microscopic

examination however nepheline is found to be completely absent, the feldspar consists of oligoclase and orthoclase, the former in excess of the latter, and abundant biotite and pale green augite which are in part intergrown. Sphene, apatite, titaniferous iron ore and pyrite are accessories and minute zircons are present in more tham usual proportions.

Syenites. The dykes, at Tunnel Station 208+66 (Analysis G) and 195+38.5, are syenites. Both of these dykes are badly altered; in the first mentioned the dark mineral has been completely replaced by calcite and a dull green chloritic material, and in the second only a few shreds of biotite remain. Both are pink in colour, medium grained and possess hypidiomorphic structure. In thin sections, albite and orthoclase appear in about equal proportions. Microperthitic intergrowths are common and in a few individuals a micrographic intergrowth appears. Sphene, zircon, and titaniferous iron ore and apatite are accessories. The feldspar is fairly fresh but shows some alteration to calcite and kaolin together with a little staining with hematite.

Shonkinite porphyry. An interesting porphyritic dyke, thirty inches wide, occurs at Tunnel Station 254+06 (Analysis F) in the vicinity of the older nepheline-syenite porphyries. It is grey in colour and contains prominent phenocrysts of black hornblende and augite up to a half an inch long. Feldspar phenocrysts though abundant are somewhat less prominent

In the finer grained groundmass the same minerals can be distinguished. It holds a number of inclusions of essexite. In thin sections, the hornblende is pleochroic from yellowish green to deep green while some crystals show brown interiors and green margins. The augite is very pale green or almost colourless often with slightly greener margins. Both some of the hornblendes and some of the augites show incipient alteration to calcite, chlorite and a little iron ore dust, the latter especially in the case of the hornblendes. The abundant phenocrysts of plagioclase are zoned from acid labradorite, at the centre, to intermediate oligoclase. Numerous grains, or wedge-shaped crystals, of sphene are present often showing alterations to calcite and to grains of black iron ore around their margins. Dusty nosean often showing idiomorphic outlines is particularly abundant and is often poikilitically enclosed in the larger augite and hornblende phenocrysts. One large individual of augite contains forty-two small rounded grains of nosean. Quite large grains of titaniferous iron ore and pyrite are distributed through the rock and prisms of apatite are quite abundant, especially in the hornblende and augite phenocrysts, or enclosed in the larger grains of iron ore. The groundmass consists of little irregularly disposed laths of albite-oligoclase with slightly subordinate grains of orthoclase and a fair number of grains of nepheline. Scattered through this are minor grains of iron ore and pyrite with much diffused calcite and a little sericite.

Some difficulty has been experienced in correctly naming this rock, for it is in reality a type intermediate between essexite and shonkinite. The character of the feldspar separates it from the shonkinites, and yet the rock hardly seems calcic enough or rich enough in dark constituents to be termed an essexite. Chemically it is most closely allied to the shonkinites and rather than add to an already voluminous nomenclature it has been called shonkinite-porphyry, keeping in mind the above reservations.

ANALYSES

Seven analyses are given of the various rocks described and with one exception these have not been published previously. All of these analyses were made by M.F.Connor of the Geological Survey of Canada. In the calculation of the norm of the nordmarkite-pegmatite it was necessary to form 0.34% of magnesium carbonate, as sufficient lime is not present to balance the carbon dioxide. The norm for the altered pink syenite has not been calculated as there is a considerable deficiency of lime, necessary to form calcite, and an adjustment as in the last case is not deemed advisable.

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thanks are also due to Prof. R.P.D.Graham and Dr. J.J.O'Neill for many valuable suggestions.

SPECIMENS ANALYSED

Name and Symbol.	Locality.	Classification.
A. Nepheline-syenite I.(5)6.1"."4.	Older nepheline-syenite in Corporation Quarry	Class I Persalane Order (5)6 Russare Rang 1" Miaskase Subrang "4 Miaskose
B. Nepheline-syenite I.6.1.4.	Younger nepheline-syenite. Mount Royal Tunnel Station 252+71.	Class I Persalane Order 6 Russare Rang 1 Miaskase Subrang 4 Miaskose
C. Nepheline-syenite I".5'.2.(3)4.	Younger nepheline-syenite. Mount Royal Tunnel Station 252+50	Class I" Persalane Order 5' Canadare Rang 2 Pulaskase Subrang (3)4 Pulaskose
D. Nordmarkite pegmatite I.5.1.3.	Mount Royal Tunnel Station 197+58	Class I Persalane Order 5 Canadare Rang 1 Normarkase Subrang 3 Phlegrose
E. Soda-rich monzonite II.5.(2)3.4'.	Mount Royal Tunnel Station 229+05	Class II Dosolane Order 5 Germanare Rang (2)3 Andase Subrang 4' Andose
F. Shonkinite-porphyry (I)II.6.2.4.	Mount Royal Tunnel Station 254+06	Class (I)II Dosolane Order 6 Norgare Rang 2 Essexase Subrang 4 Essexose
G. Syenite	Mount Royal Tunnel Station 208+66	Not calculated due to alteration

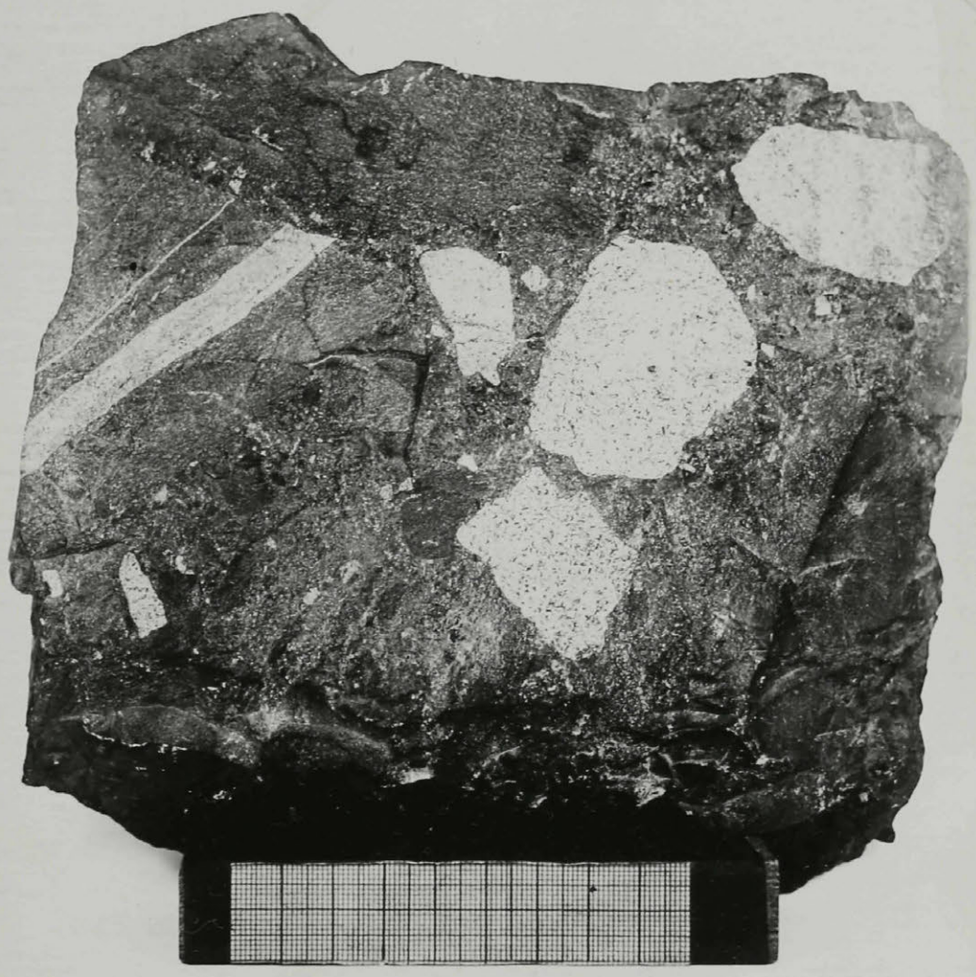
	A	B	C	D	E	F	G
SiO_2	55.90	56.28	56.30	63.20	53.84	49.84	58.20
Al_2O_3	19.75	22.53	20.96	18.94	19.68	19.46	17.57
Fe_2O_3	1.00	1.14	2.04	0.27	2.64	2.67	1.94
FeO	2.05	0.90	1.58	1.00	4.37	2.82	1.43
MgO	0.59	0.23	0.49	0.38	2.06	1.55	0.78
CaO	3.10	1.50	3.28	1.50	6.60	6.06	3.77
Na_2O	7.25	10.25	6.57	5.84	6.24	8.04	6.14
K_2O	5.61	5.46	5.69	7.56	2.10	3.18	4.80
H_2O	2.00	0.90	1.40	0.11	0.25	1.45	0.74
CO_2	1.85	0.45	0.31	1.30	trace	2.03	3.48
TiO_2	0.70	0.25	0.60	0.10	1.50	1.54	0.36
P_2O_5	0.01	0.06	0.09	0.10	0.36	0.42	0.18
SO_3	0.04	0.20	0.20	0.14	0.26	0.40	0.11
Cl	trace	0.09	0.17	0.14	0.19	0.15	0.10
$Fe\ S_2$	.....	.....	0.30	0.04	.....	0.17	0.12
Fe_7S_8	.....	.....	0.01	0.02	.....	.....	.....
MnO	0.10	0.13	0.09	0.03	0.12	0.20	0.05
SrO	trace	.....	0.04	0.04	.....	.....	0.07
BaO	0.09	.....	0.21	0.05	.....	.....	0.21
S	0.64	0.27	.....	.....	0.15	.....	.....
Cr_2O_3	.....	.....	.....	.....	.....	none	.....
NiO	.....	.....	.....	.....	.....	none	.....
	100.77	100.38	100.27	99.86	100.12	99.98	100.05

NORMS

	A.	B.	C.	D.	E.	F.	G.
Orthoclase	33.36	32.25	33.92	44.48	12.23	18.90	
Albite	39.30	31.44	35.63	47.16	42.44	35.11	
Anorthite	4.17	0.28	12.79	...	21.13	10.29	
Nepheline	11.93	28.97	8.52	0.57	4.83	15.34	
Corundum	0.10	...	...	1.53	...	...	
Halite	...	...	0.59	0.23	0.35	0.23	
Thenardite	...	0.43	0.43	...	...	0.71	
Diopside	...	1.30	0.88	....	7.94	3.52	
Hypersthene	...	...	...	1.95	...	...	
Olivine	1.56	...	0.83	...	3.39	2.09	
Wollastonite	...	1.16	...	...	...	...	
Magnetite	1.39	1.62	3.02	0.46	3.71	3.94	
Ilmenite	1.37	0.46	1.22	0.15	2.89	2.89	
Pyrite	1.20	0.48	0.30	0.04	0.24	0.17	
Pyrrhotite	...	...	0.01	0.02	...	...	
Apatite	...	...	0.34	0.34	0.67	1.01	

G. Not calculated due to alteration.

Dykes of younger nepheline syenite (aplitic) cutting camptonite breccia in tunnel.



Camptonite breccia including abundant fragments of nepheline syenite, essexite, camptonite, and a fragment of dyke of camptonite cut by a small dyke of older nepheline syenite.

Nepheline syenite pegmatite cutting Trenton limestone.

Contact (A) between Trenton limestone and camptonite breccia. The breccia holds fragments of nepheline syenite, essexite, camptonite, a few very small inclusions of Potsdam sandstone and is cut by irregular dykelets of younger nepheline syenite.

Author Finley, F.I.

Title The Nepheline-Syenites and pegmatites

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