Technical and Bibliographic Notes / Notes techniques et bibliographiques

The Institute has attempted to obtain the best original copy available for filming. Features of this copy which may be bibliographically unique, which may alter any of the images in the reproduction, or which may significantly change the usual method of filming, are checked below.

L'Institut a microfilmé le meilleur exemplaire qu'il lui a été possible de se procurer. Les détails de cet exemplaire qui sont peut-être uniques du point de vue bibliographique, qui peuvent modifier une image reproduite, ou qui peuvent exiger une modification dans la méthode normale de filmage sont indiqués ci-dessous.

- [x] Coloured covers/ Couverture de couleur
- [x] Covers damaged/ Couverture endommagée
- [x] Covers restored and/or laminated/ Couverture restaurée et/ou pelliculée
- [ ] Cover title missing/ Le titre de couverture manque
- [ ] Coloured maps/ Cartes géographiques en couleur
- [ ] Coloured ink (i.e. other than blue or black)/ Encre de couleur (i.e. autre que bleue ou noire)
- [ ] Coloured plates and/or illustrations/ Planches et/ou illustrations en couleur
- [ ] Bound with other material/ Relié avec d'autres documents
- [ ] Tight binding may cause shadows or distortion along interior margin/ La reliure serrée peut causer de l'ombre ou de la distorsion le long de la marge intérieure
- [ ] Blank leaves added during restoration may appear within the text. Whenever possible, these have been omitted from filming/ Il se peut que certaines pages blanches ajoutées lors d'une restauration apparaissent dans le texte, mais, lorsque cela était possible, ces pages n'ont pas été filmées.

- [ ] Coloured pages/ Pages de couleur
- [ ] Pages damaged/ Pages endommagées
- [x] Pages restored and/or laminated/ Pages restaurées et/ou pelliculées
- [x] Pages discoloured, stained or foxed/ Pages décolorées, tachetées ou piquées
- [x] Pages detached/ Pages détachées
- [x] Showthrough/ Transparence
- [ ] Quality of print varies/ Qualité inégale de l'impression
- [ ] Continuous pagination/ Pagination continue
- [ ] Includes index(es)/ Comprend un (des) index

Title on header taken from:/ Le titre de l'en-tête provient:

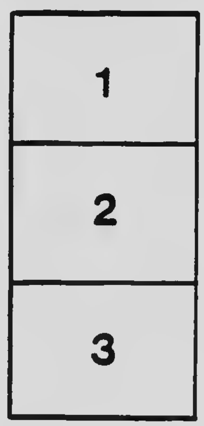
- [ ] Title page of issue/ Page de titre de la livraison
- [ ] Caption of issue/ Titre de départ de la livraison
- [ ] Masthead/ Générique (périodiques) de la livraison

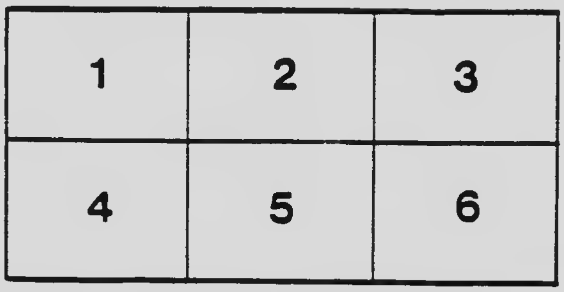
- [x] Additional comments:/ Commentaires supplémentaires: Pagination is as follows: p. [239]-282.

This item is filmed at the reduction ratio checked below/
Ce document est filmé au taux de réduction indiqué ci-dessous.

10X		14X		18X		22X		26X		30X	
	12X		16X		20X	✓ 24X		28X			32X

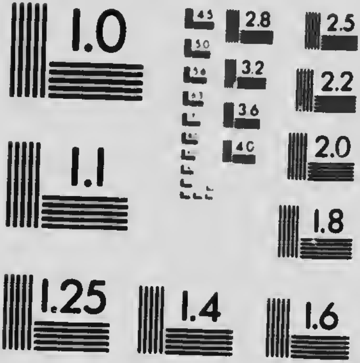

1
2
3


1
2
3


1
2
3
4
5
6

MICROCOPY RESOLUTION TEST CHART

(ANSI and ISO TEST CHART No. 2)



APPLIED IMAGE Inc
1653 East Main Street
Rochester, New York 14609 USA
(716) 482 - 0300 - Phone
(716) 288 - 5989 - Fax

McGILL UNIVERSITY

PAPERS FROM THE DEPARTMENT

OF

GEOLOGY.

No. 14.—THE MONTEREGIAN HILLS—A CANADIAN PETROGRAPHICAL PROVINCE.

BY

FRANK D. ADAMS, PH.D.

[Reprinted from the Journal of Geology, Vol xi., No. 3, April-May, 1903.]

MONTREAL, 1903.

Reprinted from the JOURNAL OF GEOLOGY, Vol. XI, No. 3, April-May, 1903

THE
JOURNAL OF GEOLOGY

APRIL-MAY, 1903

THE MONTEREGIAN HILLS—A CANADIAN PETROGRAPHICAL PROVINCE.

GENERAL STATEMENT.

In the province of Quebec between the enormous expanse of the Laurentian highlands to the northwest, constituting the "Canadian Shield," and the disturbed and folded tract of country to the southeast which marks the Appalachian uplift, there is a great plain underlain by nearly horizontal rocks of Lower Paleozoic age. This plain, while really showing slight differences of level from place to place, seems to the casual observer perfectly flat. Its surface is mantled with a fertile soil consisting of drift redistributed upon its surface by the sea which at the close of glacial times covered it. The uniform expanse of this plain, however, is broken by several isolated hills composed of igneous rocks, which rise abruptly from it and which constitute very striking features of the landscape. It was at the foot of one of these hills rising by the side of the river St. Lawrence, and which he named Mount Royal, that Jacques Cartier on his first visit found the Indian encampment of Hochelaga, whose site is now overspread by the city of Montreal, which has not only grown around the foot of the hill, but has extended up its sides and has reserved its summit as a park.

From the top of Mount Royal the other hills referred to can all be seen rising from the plain to the east, while to the north the plain stretches away unbroken to the foot of the Laurentian country.

As has been remarked by Sir Archibald Geikie:[1]

The word "mountain" is properly speaking not a scientific term. It includes many forms of ground utterly different from each other in size, shape, structure, and origin. In a really mountainous country the word would be restricted to the loftier masses of ground, while such a word as "hill" would be given to the lesser heights. But in a region of low or gently undulating land, where any conspicuous eminence becomes important, the term "mountain" is lavishly used. In eastern America this habit has been indulged in to such an extent that what are, so to speak, mere hummocks in the general landscape are dignified by the name of mountain.

The hills under consideration, while by no means "mere hummocks," being situated in such a country of low relief, seem to be higher than they really are and are always referred to locally as "mountains."

These mountains, whose positions are shown on the accompanying map (Fig. 1), are eight in number, their names and their height above sea level being as follows:

Mount Royal	769.6 feet
Montarville or Boucherville mountain	Not yet accurately determined
Beloeil	1,437 feet (Leroy)
Rougemont	Not yet accurately determined
Yamaska	Not yet accurately determined
Shefford	1,600 feet (Dresser)
Brome	1,440 feet (Dresser)
Mount Johnson or Monnoir	875 feet

Brome mountain is by far the largest of the group, having an area of 30 square miles. Shefford comes next in size, having an area of rather less than nine square miles, while Mount Johnson, which is very much smaller than any of the others, has an area of only .422 of one square mile.

Of these eight, the first six, as Logan[2] notes, "stand pretty nearly in a straight line," running approximately east and west, Mount Royal being the most westerly, and the others following in the order in which they are enumerated above, until Shefford mountain is reached, which is the most easterly member of the series. The distance from Mount Royal to Shefford is fifty

[1] *Text Book of Geology.* [2] *Geology of Canada*, p. 9.

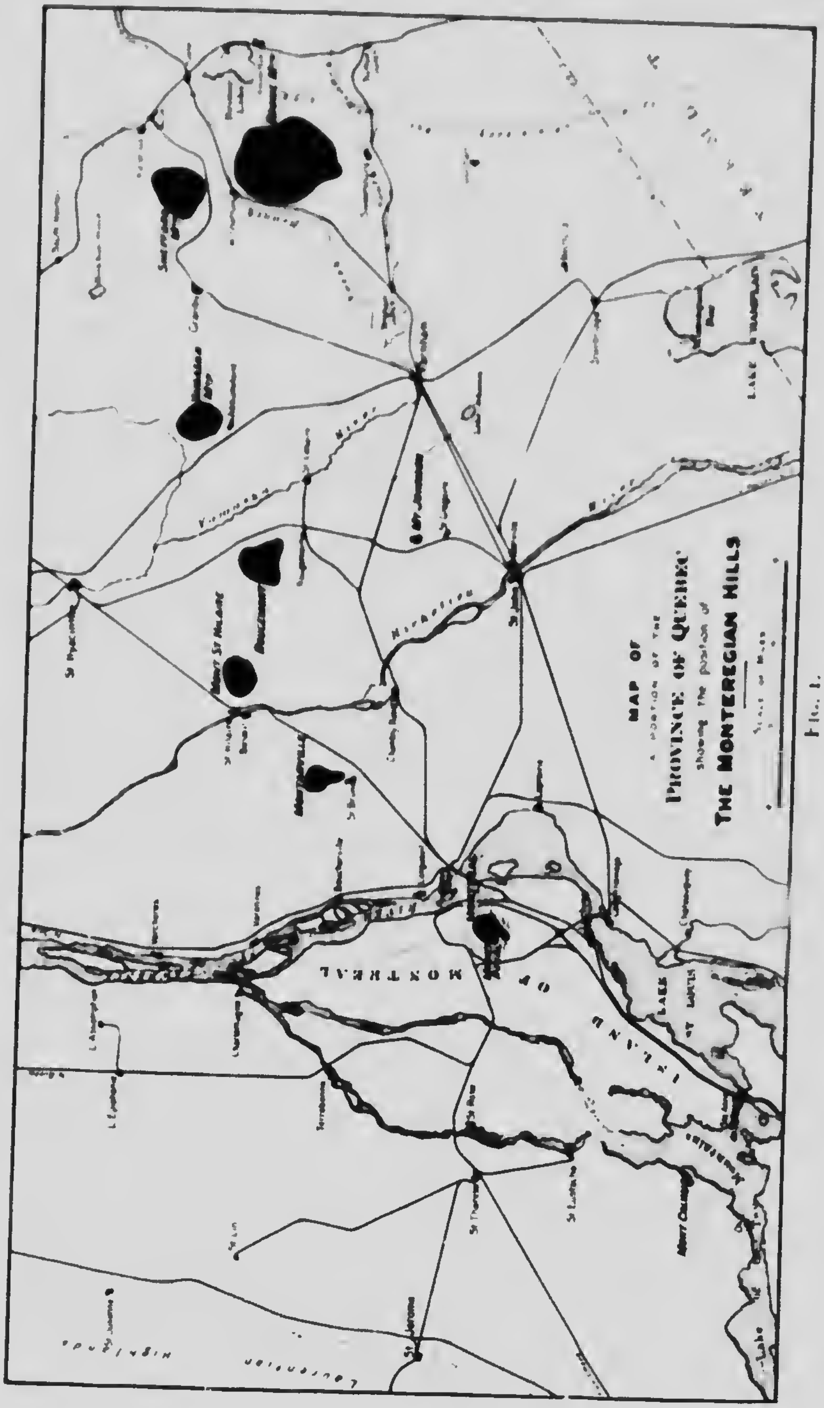

MAP OF
A PORTION OF THE
PROVINCE OF QUEBEC
showing the position of
THE MONTEREGIAN HILLS
MONTREAL
ISLAND OF MONTREAL

FIG. 1.

miles. Mount Johnson and Brome mountain lie on a line parallel to them, but a short distance to the south, Rougemont being the nearest neighbor to Mount Johnson and Brome mountain being immediately south of Shefford. It is highly probable, in view of this distribution, that these ancient volcanic mountains are, as is usual in such occurrences, arranged along some line or lines of weakness or deep-seated fracture. The "pretty nearly straight line" referred to by Logan on which the first six mountains of the group are situated must be considered either as a single line with a rather sharp curve in the middle, or as made up of two shorter straight lines, each with three mountains, which diverge from one another at an angle of about 30°, Montarville being located at the point of intersection. Mount Johnson and Brome mountain might then be considered as situated on short subsidiary fractures.

Brome and Shefford, however, which are the two largest mountains of the series and which are only separated by a distance of a little over two miles, are probably connected at no great depth below the surface, forming in reality one large mass, while Mount Johnson, like the similar volcanic necks of Fife and Würtemberg, may have no direct connection with any line of fracture. It must be noted, as mentioned by Dresser,[1] that while six of these mountains rise from the horizontal strata of the plain, the two most easterly members of the group, named Shefford and Brome, while still to the west of the axis of the range, lie well within the folded belt of the Appalachians, though, owing to the extensive denudation from which the region has suffered, this folding has had but little influence on the local topography.

No collective name has hitherto been proposed for this remarkable group of hills.[2] From their intimate geological

[1] "On the Petrography of Shefford Mountain," *Amer. Geol.*, October, 1901.

[2] The only instances in which these hills have been referred to as a geographical unit are, so far as can be ascertained, in a paper by STERRY HUNT entitled "On Some Igneous Rocks of Canada," *Am. Jour. Science*, March, 1860, where they are called the Montreal group; and by ELIE DE BEAUMONT, who in a late edition of his *Systèmes des Montagnes* included these hills as one of his systems, under the name of the "Système de Montréal." See PRESTWICH, *Geology, Chemical, Physical and Stratigraphical*, Vol. I, p. 294.

relationship, however, constituting as they do a distinct and remarkable petrographical province, such a name is required. I propose to call them the *Monteregian Hills*, deriving their name from Mount Royal ("Mons Regius"), which may be taken as their type, being as it is the best-known member of the group.

There are certain other hills which have been considered by former workers in the geology of this district to belong to this group. Thus Logan thought that Rigaud Mountain, situated near the margin of the plain, by the river Ottawa, about forty miles west of Mount Royal, was "probably connected with" the series.[1] Ells[2] also included Mont Calvaire, a large, low mass which rises from the plain immediately to the north of the Lake of Two Mountains, near the junction of the Ottawa and the St. Lawrence.

Ells also refers to "the hills on the west side of Memphremagog lake and to the northeast toward the Chaudiere river and beyond" as bearing a marked resemblance to the rocks of Mount Royal, Yamaska, etc., and as probably being of the same age.[3]

In a careful study of Rigaud mountain, recently completed by Mr. Leroy,[4] of this university, it is shown that the rocks constituting this mountain are different in character from those of the Monteregian hills, being composed of a reddish hornblende syenite and a quartz-bearing porphyry. These rocks, however, were found to be identical in character and composition with a great area of syenite, cut by porphyry, mentioned by Logan as occupying some forty square miles in the townships of Chatham and Grenville on the margin of the Laurentian plateau, a few miles to the north of Rigaud mountain. Owing to the drift which mantles this district, the actual contact of the igneous rock of Rigaud mountain and the Paleozoic strata of the plain is

[1] *Geology of Canada*, 1863, p. 9.

[2] "Report on a Portion of the Province of Quebec," *Ann. Rept. Geol. Surv. of Canada*, Vol. VII, Part J, 1896.

[3] Eastern Townships Map (Montreal Sheet), *Ann. Rept. Geol. Surv. of Canada*, Vol. VII, Part J.

[4] *Bull. of the American Geological Society*, Vol. XII, 1901.

nowhere visible, so that it is impossible to determine whether the mass of Rigaud mountain cuts through the strata in question, as in the case of the Monteregian hills, or whether it is pre-Paleozoic in age. The same is true of the mass in Chatham and Grenville, the actual contact here also being found by Mr. Leroy to be banked up with drift. The narrow margin of gneiss shown on Logan's map[1] between the Chatham syenite and the Paleozoic is also conjectural, the area being likewise drift-covered. Rigaud mountain is furthermore of a different shape from the mountains east of Montreal, being six miles in length and only two and one-half miles wide; at the eastern end of it, moreover, there is found an occurrence of ordinary Laurentian gneiss. The abrupt and straight southern boundary of the Laurentian plateau along this part of its course probably marks a fault. Ells has noted the existence of other faults in this district, one of which he believes to follow the north side of Rigaud mountain. It is thus highly probable that the ridge known as Rigaud mountain does not belong to the Monteregian hills, but that it is a portion of the Laurentian plateau separated from the main area by faulting and stripped of its original covers of Paleozoic strata by denudation. It is probable that Mont Calvaire, as regarded by Logan, is also an outlying portion of the Laurentian plateau.

The hills on the west side of Lake Memphremagog and to the northeast toward the Chaudière river, referred to by Dr. Ells, so far as is known, are quite different in petrographical character from Mount Royal and the other members of its group. They constitute a chain of hills occupying a tract of country some four miles wide and thirty-five miles in length, in the heart of the Appalachian uplift and following the strike of the Appalachian folding. Many of them, as Owl's Head and Orford mountain, rise to a very considerable height, these peaks having a height of about 2,400 and 2,800 feet respectively; forming, in fact, the highest elevations in this part of Canada. So far as has been ascertained, these mountains are in all cases composed of

[1] Atlas to accompany the *Geology of Canada*, 1863, Map No. 2.

highly altered rocks. Many of them are altered diabases.[1] In other cases the alteration is so far advanced that it is impossible to determine the character of the original rock. Many of them have been completely altered to masses of serpentine. Nepheline-syenites, essexites, and similar rocks have not as yet been found anywhere in this chain of hills. A series of dyke rocks from Lake Memphremagog, examined by Marsters,[2] were found to be chiefly granites and lamprophyres, with one typical camptonite. It would seem therefore, that while our knowledge of these hills is as yet very imperfect, the evidence at our command, so far as it goes, points to them as belonging to a group quite distinct from Mount Royal and its associates. The petrographical province of the Monteregian hills may therefore, in the present state of our knowledge, be said to comprise only the eight mountains enumerated on p. 240, together with the consanguineous dykes which at many points are found cutting the rocks of the surrounding plains.

The first description of these hills was that given by Logan and Hunt in the early years of the Canadian Survey. To Hunt especially we owe a somewhat extended description of the petrography of the group and a number of chemical analyses, more especially of the constituent minerals of certain of the rocks. These descriptions are, however, very general and often very imperfect, as must necessarily have been the case before the introduction of modern petrographical methods. Nor were certain important petrographical relationships observed which have in later times come to be recognized. This early work, however, is of great interest, and in case of three of the mountains almost all the information which we have even at the present time, is derived from those early studies. The results of this work were brought together in the *Geology of Canada*, published by the Geological Survey of Canada in 1863, and are to be found on pp. 655-70. During the thirty years following the appearance of this volume, only three papers containing additional information concerning these rocks appeared. These were by

[1] F. D. Adams, *Ann. Rept. Geol. Surv. of Canada*, 1880-81-82, pp. 12-13 A.
[2] *American Geologist*, July, 1895.

Harrington,[1] Lacroix,[2] and the present writer,[3] respectively, all dealing with Mount Royal. In 1896 the "Montreal Sheet" of the *Eastern Townships Map*, prepared by Ells, and embracing the district of the Monteregian hills, was published by the Geological Survey of Canada and accompanied by a geological report on this portion of the province of Quebec. Four years later Principal Dresser of St. Francis College, Richmond, aided by a small grant from the Geological Survey of Canada, made a careful study of Shefford mountain, and a preliminary paper embodying the chief results of his investigations appeared in 1901.[4] Mr. Dresser last summer extended his work to Brome mountain, and has since published a brief description of this occurrence.[5] Mr. O. E. Leroy, of McGill University, is now engaged in a study of Beloeil, and I am indebted to him for the facts concerning the geology of this mountain which are here presented. Montarville, Rougemont, and Yamaska mountains still await detailed study, but it is expected that they also will before long be put in commission.

In the present paper it is proposed first to gather together the more important facts concerning the geology of the Monteregian hills which are scattered throughout these various publications, revising some of the earlier work and embodying the results of later personal studies, and then to describe in some detail one of these hills—Mount Johnson—of which hitherto but little has been known.

PETROGRAPHY OF THE MONTEREGIAN HILLS.

Hunt distinguished four types of igneous rocks as constituents of the Monteregian hills. These he classed as trachyte,

[1] "On Some of the Diorites of Montreal," *Ann. Rept. of the Geol. Surv. of Canada*, 1877–78, 42 G.

[2] "Description des syénites néphélinitiques de Pousac et de Montréal (Canada) et de leurs phénomènes de contact," *Bull. Soc. Géol. de France*, 3e série, tome XVIII, 1890.

[3] "On a Melilite-Bearing Rock (Alnöite) from St. Anne de Bellevue near Montreal, Canada," *Amer. Jour. of Science*, April, 1892.

[4] "On the Petrography of Shefford Mountain," *Amer. Geol.*, October, 1901.

[5] *Summary Report of the Geological Survey Department for 1901*, p. 183.

phonolite, diorite, and dolerite, respectively. In this classification no distinction was made between rocks occurring as dykes and the great igneous intrusions which form the body of the hills; differences in structure resulting from mode of occurrence were not considered, the classification being based upon mineralogical composition alone.

Recent investigations have shown that Hunt's names do not convey an accurate idea of the petrography of these hills, nor do they set forth the interesting relationships of the various rocks composing them. It is necessary for this purpose to adopt a more modern nomenclature, for all the mountains of the group are composed of a family of consanguineous rocks, and taken together they present one of the finest examples of a petrographical province hitherto discovered. They consist, furthermore, of a rather rare class of rocks characterized by a high content of alumina and alkalies, especially soda.

The rocks forming the great intrusions which make up the mass of these mountains belong to two well-characterized types—one light in color, poor in iron-magnesia constituents, and comparatively high in silica; the other dark in color, rich in iron-magnesia constituents, and with a lower content of silica. They may be classed as follows, if Rosenbusch's nomenclature be followed:

1. Alkali-syenite, nepheline-syenite, or sodalite-syenite.
2. Essexite.

The first is an alkali-syenite, always containing a little nepheline, but this mineral in some cases becoming so abundant that the rock passes into a true nepheline-syenite, or, by the replacement of the nepheline by sodalite into a sodalite-syenite. This in the case of Mount Johnson and Shefford mountain is represented by the variety known as pulaskite; in Brome mountain it is stated by Dresser to resemble Brögger's laurvikite,[1] while in Mount Royal and Beloeil it is a nepheline-syenite. At the latter mountain a sodalite-syenite also occurs in association with the nepheline-syenite. Nepheline-syenite is also known to form part of Yamaska mountain. In addition to the syenite of the

[1] *Summary Report of the Geological Survey of Canada*, 1901, p. 187.

pulaskite variety, Dresser found in Shefford mountain a large development of a distinctly more acid type of the syenite magma, the rock showing occasionally a few grains of quartz. This rock he has classed as nordmarkite. These light-colored syenites, together with certain dykes of bostonite having a general similarity in composition, were the rocks classed by Dr. Hunt as trachytes.

To the essexites belong the dolerites and diorites of Hunt, when he applied these terms to the great igneous intrusions of the mountains and not to mere dykes. They usually contain both hornblende and pyroxene, but the relative proportion of these two minerals varies considerably in the different occurrences. Olivine is sometimes present. Hunt did not recognize the presence of nepheline in these rocks, nor the highly alkaline character of the magma which they represent, and classified them as dolerite or diorite according to the preponderance of pyroxene or hornblende, noticing certain occurrences in which the former rock passed into a pyroxenite or peridotite.

The greater part of Mount Royal is composed of an essexite, usually very basic, the dark-colored constituents forming a very large proportion of the whole rock. This was classed by Hunt as a dolerite, but is almost identical with the essexite of Mount Johnson, which Hunt classes as a diorite. This same rock is stated by Hunt to make up the greater part of Montarville and Rougemont and to form a portion of Yamaska mountain. An examination of thin sections of specimens of the Rougemont rock in the petrographical collection at McGill University shows it to be an essexite, rich in olivine. Dresser has found it to constitute approximately one-half of Shefford mountain and also to form large areas in Brome mountain. It makes up the greater part of Mount Johnson and forms the mass of Beloeil.

It is thus seen that the essexite magma is represented in every one of the eight mountains, and that in six of them at least it is associated with the syenite magma. The remaining two, Montarville and Rougemont, which have not been thoroughly examined as yet, while certainly composed chiefly of essexite, will probably be found, on further study, to present a development of the syenite in some portions of their mass also.

In addition to these bodies of intrusive rock which form the mass of the mountains, great numbers of dykes occur cutting both the surrounding sedimentary strata and the intrusions. These are, of course, especially numerous in and around the mountains themselves, but are also occasionally found far removed from the centers of activity. The relative abundance of these dykes in the vicinity of the several mountains varies greatly. They swarm through the Paleozoic strata about Mount Royal, cutting the limestones in all directions and also traversing, although less frequently, the igneous rock of the main intrusion as well. No less than twenty-nine dykes and flows, belonging to at least four and possibly five separate series, each cutting the preceding set, were mapped by Dr. Harrington some years ago in an excavation measuring 220 yards by 100 yards which was opened up in the Trenton limestone on the flank of Mount Royal during the construction of the Montreal Reservoir extension. Dykes, in fact, abound wherever in the vicinity of Mount Royal the bed-rock is exposed by the removal of the mantle of drift, as for instance at the Mile End Quarries, St. Helen's Island, and in the bed of the St. Lawrence about Point St. Charles when it is exposed at low water. The whole district about the city would present a network of dykes, could the overlying drift be removed.

Dresser mentions dykes as occurring abundantly about Shefford mountain. In Mount Johnson, on the other hand, they are almost entirely absent. Only five dykes could be found after a careful exploration of the whole occurrence, and they were of insignificent dimensions. But very few dykes also occur at Beloeil mountain. A large number of the dyke rocks have been collected from the various occurrences and are now awaiting investigation in the geological department at McGill University. The work on the dykes of Mount Royal is now well advanced and, it is hoped, will be ready for publication shortly. They form a most remarkable series, comprising bostonites, tinguaites, sölvsbergites, camptonites, fourchites, monchiquites, and alnöites. Most, if not all, of the types of dyke rocks which have been described as occurring in association with the alkaline rich magmas of the theralite and nepheline-syenite groups in any part of the world are thus represented. To these dyke rocks belong Hunt's phonolite, which he considered to differ from the trachyte in that it contained a certain proportion of natrolite. The two occurrences which he describes [1] are both from points near Montreal. They are nepheline bearing dykes in an advanced stage of alteration.

As has been mentioned, dyke rocks which from their composition are clearly connected with the intrusions of the Monteregian hills have been found cutting the rocks of the plain at very considerable distances from any of the main centers of activity. Thus, in addition to occurrences at Laprairie, Lachine, Rivière des Prairies, Ste. Anne de Bellevue, St. Paul's Island in the vicinity of Montreal, several dykes and flows of "trachyte" (bostonite) are noted by Hunt and Logan as occurring about Chambly, which is six miles to the south of the line of the Monteregian hills,[2] while the occurrence of a "dolerite" dyke at St. Hyacinth, ten miles north of the line, is mentioned.[3]

A sheet of trap evidently connected with these intrusions also occurs at St. Lin,[4] twenty-four miles north of this line, where it alters the Chazy limestones through which it cuts into a pink marble. It is very much decomposed, but evidently belongs to some variety of the nepheline or melilite dyke rocks above mentioned.[5]

Whether the camptonite and in some cases bostonite dykes, described by several authors from various points in the states of Maine, New Hampshire, and Vermont, adjacent to the Canadian line, and the still more distant occurrences of similar dyke rocks in the state of New York, are connected with the Monteregian hills, is not yet known. There seem to be no intrusions of nepheline-syenite or essexite hitherto discovered with which these southern dykes can be connected in the districts in which they occur. The umptekite intrusion of Red Hill, Molton-

[1] *Geology of Canada*, pp. 659–61.

[2] *Ibid.*, pp. 209 and 657.

[3] *Ibid.*, p. 210.

[4] *Ibid.*, p. 133.

[5] F. D. Adams, "Report of Geology of Laurentian Area to North of Island of Montreal," *Ann. Rept. Geol. Surv. of Canada*, Vol. VIII, J, p. 139, 1896.

boro, N. H., is, however, closely related to the Monteregian pulaskite in character and composition, and may prove to be such a center.

STRUCTURE AND ORIGIN OF THE MONTEREGIAN HILLS.

The question of the mutual relations and relative age of the several rock types constituting these hills presents many points of interest. In the case of Mount Royal the essexite which constitutes the greater part of the mountain was the earliest intrusion. When this had become solid the nepheline-syenite broke through it, sending arms into it and catching up detached fragments of the shattered essexite. The same sequence in time is, according to Dresser, to be seen in Shefford Mountain. The basic essexite here forms the earliest intrusion, and was succeeded by the pulaskite and more acid nordmarkite. Mount Johnson, however, presents the two rocks in an entirely different relation. Here, as will be shown later, there was but a single period of intrusion. For although both rocks are present in the mountain, the essexite forms the central portion of the mass and passes over into pulaskite about the periphery of the neck. The mountain thus consists of essexite in its center, surrounded by a zone of pulaskite, the two rocks passing imperceptibly into one another. Mr. Leroy considers it probable that a similar passage takes place in the case of Beloeil mountain, but it is there difficult accurately to determine the relations of the magmas to one another on account of the covering of drift which obscures the contact.

It is thus evident that the two rock types constituting the Monteregian hills are differentiation products of a single magma, the separated magmas, however, in the case of Mount Royal and Shefford having been erupted in succession instead of simultaneously. In connection with the question of differentiation, another noteworthy fact is that the more easterly mountains contain proportionately more syenite and the western hills a greater proportion of the essexite. The bearing of this fact on the character of the differentiation which took place in the subterranean magma basin can be more profitably discussed at a later date when the precise character and relative extent of the intrusions in Yamaska, Rougemont, and Montarville have been det mined.

With regard to the structure of these mountains, it may noted that Logan, who first examined them, refers to them "intrusive masses breaking through the surrounding Paleoz strata."[1] They are thus represented in the geological sectic of this district contained in the atlas accompanying his repo Ells refers to them simply as "eruptive mountains."[2] The mo detailed studies of Shefford and Brome mountains recent carried out by Dresser, however, have led him to consider the two occurrences as uncovered laccolites. Concerning Sheffo mountain he says:

> The sedimentary strata which surround the mountain . . . . are fou to wrap around the igneous mass of the mountain, mantling it with hardened contact zone to a height of 300 to 1,000 feet above the surroundi country, according to the direction of glaciation. Above the latter heig the mountain rises upward of 200 feet, the summit being capped by outlier of Trenton slate about a quarter of a mile in extent. This preserv the cleavage, dip, and strike of the similar rock at either side of the mou tain and is penetrated by dykes from the underlying igneous rocks. Fro these facts, together with the absence of tufaceous material and the gener arching of the strata around the mountain, it is inferred that Shefford mou tain is an uncovered laccolite rather than the denuded neck of a once acti volcano.[3]

In Brome mountain also the presence of outlying masses of th surrounding sedimentary series at high levels lying upon th igneous rock of the intrusion "seem to indicate unmistakabl that Brome mountain, like Shefford, is an uncovered laccolit and has never been an active volcano."[4]

Mount Johnson, on the contrary, as will be shown, is a typica neck or plug, representing a portion of the conduit throug which the magma rose, to fill laccolites above in strata which have long since been swept away by erosion, or to be poured out at the surface at volcanic vents. This is seen by the fact

[1] *Geology of Canada*, p. 655.

[2] *Ann. Rept. of Geol. Surv. of Canada*, Vol. VII, J, p. 71.

[3] *American Geologist*, October, 1901, p. 204.

[4] *Geol. Surv. of Canada, Summary Rept. for 1901*, p. 187.

that the flat-lying strata all about it are not arched up, but abut sharply against the igneous core of the mountain and are cut off by it. Being shales, they are of course baked to hornstones, but show no signs of upheaval or tilting. The small size and almost circular cross-section of the mountain are a further indication of this origin; and finally there is conclusive proof that there was a vertical or upward movement of molten rock through the pipe. The mountain has been figured by Professor Davis, in his *Physical Geography*, from one of the author's photographs, as a typical example of a volcanic neck.

In a recent paper by Buchan[1] 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, toward the summit, there is an isolated mass of flat-lying, altered Paleozoic limestone, evidently a part of the sedimentary 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 their 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. The occurrences of the flat-lying limestone on the side of the mountain referred to above appear to represent the remnant of certain beds, beneath which a portion of the intrusive mass penetrated, after the manner of a laccolite, on one side of the mass. Their existence does not by any means indicate a laccolitic structure for the mountains as a whole, or that the igneous material did not find a vent at the surface, there developing a volcano. In fact, there is evidence in the existence of a remarkable deposit of a breccia-conglomerate in several places around the mountain that it did develop as a volcano and that the materials constituting the deposit in question were ejected from it. A study of this breccia was undertaken last autumn by one of the geological field parties of McGill University, and a description of it, with a

[1] *Canadian Record of Science*, Vol. VIII (1901), p. 321.

discussion of its origin, is now in press and will appear *Canadian Record of Science* within the next few weeks. The four hills have not as yet been studied in sufficient det enable any definite statement concerning their structure made.

In the Monteregian hills there are thus intrusions o nature of laccolites, true necks, and probably also of st The age of the intrusions cannot as yet be definitely determ They are later than the lower Devonian, for some of the connected with Mount Royal cut limestones which belong t summit of the upper Silurian, while fragments of limestone are shown by the fossils which they contain to be referab the lowest beds of the Devonian, occur as inclusions in the canic breccia or agglomerate which is found about the flan the same mountain. The deeply eroded character of the m tains, however, shows that they are of early date, and it s most probable that the intrusion took place somewhere in Paleozoic times.

Having considered in a general way the character of Monteregian hills as a whole it may be of interest to look so what more closely into the structure and petrographical c acters of one member of the group which has recently studied in some detail, namely Mount Johnson.

MOUNT JOHNSON.

Mount Johnson rises from the plain twenty-two miles c southeast of the city of Montreal, and six miles northeast of town of St. Johns on the Richelieu river, and twenty-five m north of the international boundary. The little village of Grègoire is situated near its base. The surrounding countr perfectly flat, forming a fertile and well-tilled agricultural trict, the nearest mountain being Rougemont, which lies i northeasterly direction some nine miles distant. In cross-sect Mount Johnson is nearly circular. (Fig. 2.) The igneous p itself has at the base, immediately above the hornstone collar somewhat elliptical outline and measures 3,500 feet by 2,5 feet, the longer axis having a direction N 20° E. This gives

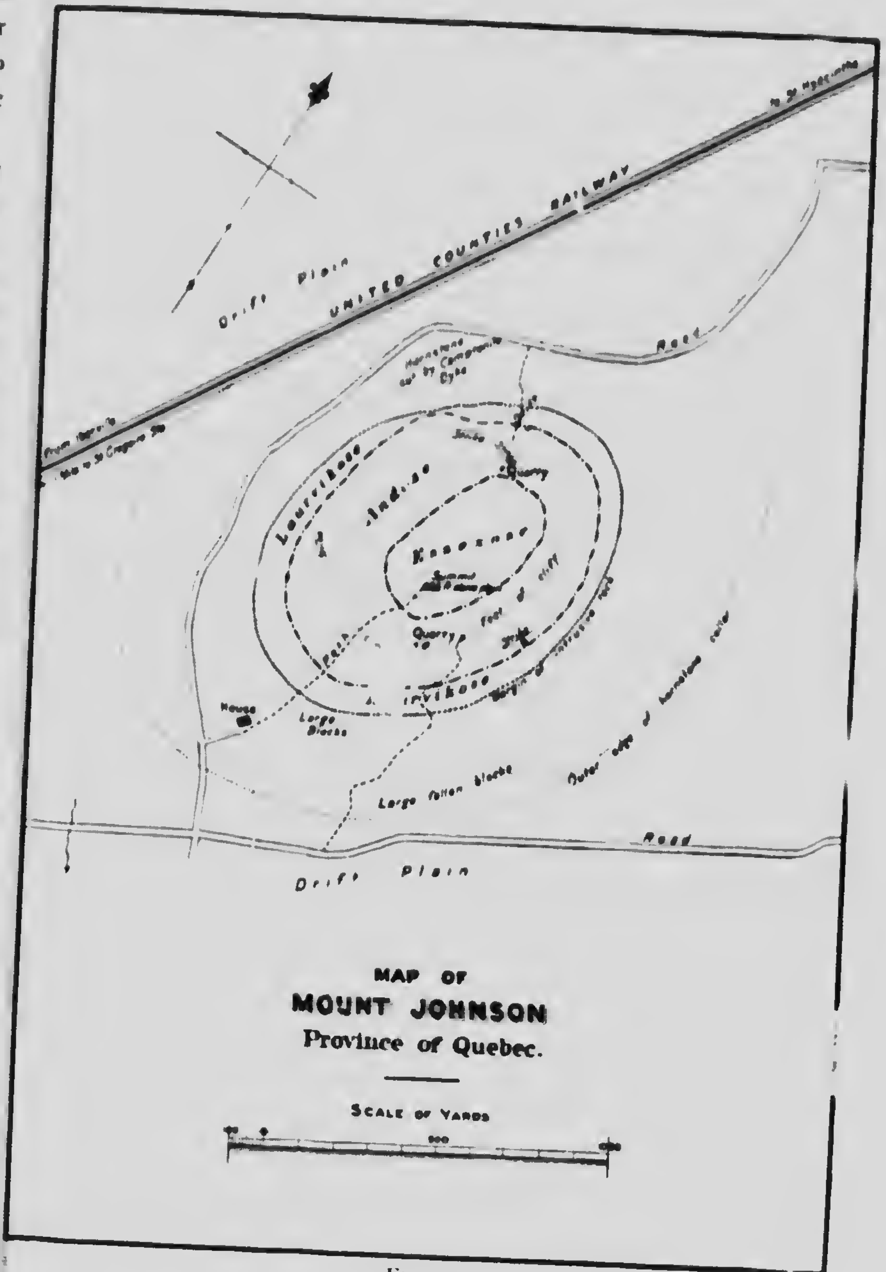

Drift Plain
UNITED COUNTIES RAILWAY
Road
Quarry
House
Large Blocks
Large fallen blocks
Road
Drift Plain
MAP OF
MOUNT JOHNSON
Province of Quebec.
Scale of Yards
500

FIG. 2.

igneous intrusion an area of .422 of a square mile. The me
series of closely concordant aneroid readings, corrected b
parison with barometers at the observatory of McGill Un
at Montreal, shows that the highest point of the mountain
feet above the main street in the village of St Gregoire o
the church, that is, above the surrounding plain, or 8
above sea-level, the plain here having an elevation above se
of 190 feet. It has a somewhat dome-like outline and f
very striking feature in the landscape. The slope on the
ern side is steep, in places precipitous, while to the nort
more gentle. The accompanying photograph (Fig. 3),
from the railway station near St. Gregoire, which is about
and a quarter distant from the mountain in a direction ap
mately southwest, shows this profile, as well as the little
near the summit caused by a ravine which passes down th

At the foot of the mountain, more especially on its sou
southeastern, and southwestern sides, are numbers of larg
which have fallen from the steep upper slopes and exte
from the foot; on the southern is a gently sloping, terrace
form of drift which in part buries these great blocks, form
"tail" probably due to the drift accumulating here on t
side of the mountain during the ice movements in the g
age. This drift, however, has been in part at least reassort
wave-action during the period of depression which in this r
followed the glacial age and during which the sea covere
plain to a depth of several hundred feet at least, as shown b
high level terraces with shell banks on the slopes of M
Royal. On the plain about the mountain no rock exposure
seen. A mantle of drift covers it, and numerous erratic b
and bowlders are scattered about. These are largely gne
from the Laurentian highlands, but some of them are plu
rocks from other hills of the Monteregian group. The
about Mount Johnson is, however, stated by Ells, who has e
ined this district, to be underlain "presumably" by rocks o
Utica-Lorraine division of the Lower Silurian.

On ascending the mountain the first rock which is exp
above the drift mantle is a very fine-grained dark hornstone,

form in character and lying in undisturbed horizontal beds. It can be seen at intervals all around the base of the mountain, forming a sort of collar, and is undoubtedly a shale such as that usually constituting the Utica formation, here however altered by its proximity to the intrusion. This shale wherever seen lies flat and abuts against the igneous rock of the intrusion, being cut sharply off by it, but not tilted or upturned. The upper limit of the shale is shown in the accompanying photograph of the mountain.

FIG. 8. — … hnson, as seen from the southwest, showing limits of the several rock types co… the mountain.

The mountain above this hornstone collar is made up exclusively of igneous material, which presents a most striking and beautiful instance of differentiation.

Immediately above the hornstone collar, and in contact with it, is a coarse-grained and highly feldspathic syenite, light buff in color, of the pulaskite type. This, as the mountain is scaled, passes rather abruptly into a dark-colored rock with large porphyritic white feldspars, which in its turn loses its porphyritic character and passes into a coarse-grained essexite which constitutes the mass of the hill and which becomes at the summit finer in grain, richer in pyroxene and often holding a little olivine. No sharp lines can be drawn between these several rocks; one

passes gradually into the other, the whole constituting one
sive unit. The approximate limits of these several rock s
are shown in the accompanying map (Fig. 2) and photo
(Fig. 3) of the mountain, it being impossible sharply to d
the several species, seeing that they pass into one another.
mass therefore becomes progressively more basic as we
from the margin of the intrusion to its center. The two
rock types are the pulaskite and the essexite which will be
rately considered. The essexite, being the more abundant
and one presenting a greater complexity in mineralogical
position, may be first described.

ESSEXITE.—The rock is dark in color and rather coar
grain, and although holocrystalline usually presents a more or
marked fluidal arrangement of the constituents. This is e
cially marked in the zone of transition between the essexite
pulaskite, owing to the presence there of the large feld
phenocysts which, being arranged with their longer axes par
to the direction of flow, serve to accentuate this structure.
finer-grained variety forming the summit of the mountain is n
massive in character and does not exhibit the fluidal arra
ment of constituents. Under the microscope the rock is see
be composed of the following minerals: hornblende, pyrox
biotite, olivine, plagioclase, nepheline, sodalite, apatite, m
netite, sphene, and in some cases a very small amount of ort
clase.

There is a marked tendency on the part of all the constitue
to assume an idiomorphic development. The long lath-sha
plagioclases and large hornblende individuals have an appro
mately parallel arrangement, and between these lie the ot
iron-magnesia constituents with the smaller plagioclase in
viduals, the nepheline and the other components of the ro
These interstitial constituents do not differ greatly in size fr
the others and show the same tendency to a parallel arrang
ment.

Hornblende.—Although almost every thin section of the ro
contains not only hornblende, but pyroxene and biotite als
their relative proportion varies considerably. The hornblen

is distinctly the most abundant, except in the finer-grained variety forming the summit of the mountain in which it is distinctly subordinate in amount to both pyroxene and mica. It is deep brown in color and is sometimes hypidiomorphic in its development, but often occurs with perfect crystalline form, showing the prismatic and the orthopinacoidal faces. Its extinction is larger than is usual in brown hornblendes, judging from the recorded instances, reaching 20°. It possesses a strong pleochroism as follows:

a = pale yellowish-brown.
b = deep-brown.
c = very deep-brown.
Absorption **c** > **b** > **a**.

It is often twinned parallel to $\infty P \infty$ or to a steep orthodome, and sometimes presents a faint zonal structure, marked by a slight difference in extinction of the several zones indicating a slight change in composition as growth proceeded, and occasionally a greenish tint is noticeable about the margin of the individual. It sometimes holds inclusions of magnetite and is often intergrown with the pyroxene. In the essexite from one place on the south side of the mountain, the hornblende was found free from inclusions, and practically free from the pyroxene which is usually so intimately associated with it. From this locality a quantity of the hornblende was obtained in a state of perfect purity through repeated separations by means of Klein's solution, all grains of foreign mineral still remaining being finally removed by picking them out by hand with the aid of a powerful lens. The pure material thus obtained was analyzed by Professor Norton Evans, of the McGill University, every precaution to secure accuracy being observed and especial care being taken to effect a complete separation of the magnesia from the alumina by the repeated precipitation of the latter. The water was estimated by a direct determination. The results of the analysis are given below, together with those of several other hornblendes of similar composition which have been added for purposes of comparison:

	No. 1	No. 2	No. 3	No. 4	No. 5
SiO_2	38.633	39.75	40.15	40.14	41.35
TiO_2	5.035	5.40	5.21	4.20	4.07
Al_2O_3	11.974	15.00	14.34	14.30	13.48
Fe_2O_3	3.903	7.86	7.80	7.07	5.14
FeO	11.523	2.80	4.53	6.27	10.33
MnO	0.729	.....	.....	0.21	.....
MgO	10.200	14.10	13.14	11.02	11.44
CaO	12.807	12.07	11.75	12.00	10.93
Na_2O	3.139	1.92	2.31	2.22	2.10
K_2O	1.489	1.61	1.14	1.35	0.62
H_2O	0.330	.....	.....	.....	0.48
	99.762	101.50	100.37	99.44	100.84

No. 1. Hornblende. From the essexite of Mount Johnson, prov
Quebec, Canada.
No. 2. Hornblende. From Bohemian Mittelgebirge.
No. 3. Hornblende. From tuff of hornblende basalt, Härtlingen, Nas
No. 4. Hornblende. Basalt tuff, Hoheberg, near Giessen.
No. 5. Hornblende. From "hornblende diabase," Gräveneck, near We
No. 6. Hornblende. Syntagmatite. Jan Mayen.
Analyses Nos. 2 to 6 are taken from Schneider's paper referred to

The hornblende thus belongs to the class of basaltic blendes, and not to the barkevikites as might be expecte contains, however, proportionally more of the iron in a fe condition, together with somewhat less alumina and a some larger proportion of alkalies than most basaltic hornble The unusually high extinction for a hornblende of this which it possesses is probably connected with the high co in ferrous iron, since Schneider [1] has shown that the extin increases with the increase of iron in this state of oxidation

Pyroxene.—This mineral occurs intimately associated often intergrown with the hornblende, both minerals freque holding many inclusions of magnetite and apatite. It is pale-greenish in color, with no perceptible pleochroism, but a marked dispersion of the bisectrices. It is usually hypi morphic, but is frequently idiomorphic, showing a distinct cl age parallel to the pinacoids, but usually none parallel to prismatic faces. It belongs to the variety of diopside-

[1] "Zur Kenntniss basaltischer Hornblenden," *Zeitschr. fur Kryst.*, 1891, p. 5

augites which occur in rocks of this class. The extinction is high, reaching 45°.

Biotite.—This is deep-brown and almost identical in color with the hornblende and is strongly pleochroic, **c** yellowish-brown, and **a** deep-brown. It occurs intimately associated with the hornblende and augite, and also frequently as a border around the iron ore. While usually present in comparatively small amount, in the finer-grained essexite forming the summit of the mountain it is much more abundant than the hornblende. In this variety of the essexite both the mica and the hornblende often possess a poikilitic structure owing to the presence of numerous inclusions of plagioclase, which mineral also often penetrates the individuals of biotite and hornblende in the form of well-developed crystals.

Olivine.—This species is found in the finer-grained variety of the essexite at the summit of the mountain, and was also observed in the thin sections from the essexite at one point on the east side of the mountain not far from the summit. It is very pale-green in color and occurs as little grains inclosed in the biotite and pyroxene.

Plagioclase.—The plagioclase in the rock has well-developed, lath-like forms and is, almost without exception, excellently twinned according to the albite law. Twinning according to the carlsbad and pericline laws is also very common, occurring in the same individuals which show the albite twinning. The laths of plagioclase can in a few cases be seen to be distinctly twisted, evidently owing to pressure exerted upon them by other crystals during the consolidation of the rock, since the rock was submitted to no dynamic action subsequent to its crystallization.

As before mentioned, all the plagioclase individuals are not of the same dimensions. There are larger laths associated with the large hornblende crystals, and between these are smaller laths. The two sets are not, however, sufficiently well marked to cause the resulting structure to be classed as porphyritic. The plagioclase in the rock is not all of the same composition, but varies somewhat, even in the same hand specimen, ranging from an extremely acid labradorite to an oligoclase. It, however, is chiefly andesine. Its character was determined by a large number of extinction measurements carried out on the albite twins, as well as by Michel-Lévy's method, which can readily be applied owing to the frequency of carlsbad twinning in association with albite twinning. These determinations were extended and checked by a number of specific-gravity determinations and separations by means of Thoulet's solution. The larger plagioclase individuals were found, in the case of the rock on the northeast side of the mountain 320 feet above the plain, to be somewhat more basic than the smaller crystals, having the composition of a basic andesine, while the latter ranged in character from andesine to oligoclase. In this case no feldspar having a specific gravity of over 2.65 was found to be present in the rock. Again in the rock of one of the quarries on the south side of the mountain, the larger feldspars tested by Michel-Lévy's method were found to have the composition of a very acid labradorite, $Ab_1\ An_1$. The results of a separation of the constituents of the rock by Thoulet's solution showed that the feldspar was almost all andesine, although it varied from $Ab_1\ An_1$ to an oligoclase. A crystal examined by Mr. Wright in Professor Rosenbusch's laboratory gave on P an extinction of $5°$–$6°$ and on M about $11°$, showing the feldspar to be on the line between andesine and labradorite. A very small amount of orthoclase was also present, forming a subordinate accessory constituent. That there is a variation in composition even in the same individual of plagioclase is indicated in many cases by marked growth rings with different extinctions in the different rings. The smaller plagioclases, although twinned in the same manner as the larger, usually have the twinning developed in a less striking manner. A certain proportion of the smaller grains are also untwinned, but most of these must be identical in character with the twinned feldspar, since the separations show that, while orthoclase is often present, it occurs in only extremely small amount. Dr. Sterry Hunt gives[1] an analysis of the feldspar from the essexite of Mount Johnson (called by him diorite). This is as follows:

[1] *Geology of Canada*, p. 477.

SiO_2	62.05
Al_2O_3	22.60
Fe_2O_3	.75
CaO	3.96
Na_2O	7.95
K_2O	1.80
Volatile	.80
	99.91

Sp. G. = 2.659.

This feldspar has the specific gravity and general composition of an acid andesine, although the high content of K_2O may possibly indicate the presence of some potash feldspar as an intergrowth.

Nepheline.—This is quite subordinate to the feldspar in amount. It possesses the usual low index of refraction, with extinction parallel to the cleavages, which latter can usually be seen. It is sometimes quite fresh, but at other times is found more or less completely altered to a mineral which occurs as little fibrous bundles, showing strong double refraction and parallel extinction. The fibers usually have a more or less distinctly parallel arrangement. This mineral remains practically unaltered when treated with concentrated hydrochloric acid for twenty minutes, although the nepheline in which it is imbedded is destroyed. It is either muscovite or kaolin. The nepheline is allotriomorphic and occurs chiefly in the corners between the larger crystals of feldspar and other minerals, and is penetrated by them. It is especially abundant in those portions of the rock which are rich in the dark-colored constituents. When occurring in this manner it appears, with the sodalite, to have been the last constituent of the rock to crystallize out. It is usually much more abundant than the sodalite. The nepheline also occurs in places as irregular-shaped lath-like inclusions in the feldspar.

Sodalite is usually, although not invariably, present. It strongly resembles the nepheline in appearance and shows the same alteration product. It is, however, quite isotropic. Like the nepheline, it occurs either in the spaces between the other minerals, cementing them together, or as inclusions in the feldspars.

Apatite.—The abundance of apatite is a distinct feature in this, as in similar rocks occurring elsewhere. It is always present and was the first constituent to crystallize out, being found in the form of perfect hexagonal prisms with double pyramidal terminations imbedded in the iron ore. It also occurs in the sphene as well as in the iron-magnesia constituents, in the nepheline, and also, although much less frequently, in the feldspar. Its large amount is shown by the high percentage of phosphoric acid in the analysis of the rock, 1.23 per cent. Another specimen of the rock in which the phosphoric acid was determined by Dr. B. J. Harrington gave 1.01 per cent. These figures represent 2.79 per cent. and 2.35 per cent. of apatite, respectively. It is usually somewhat turbid from the presence of minute dust-like inclusions.

Magnetite occurs chiefly inclosed in the iron-magnesia constituents, but is occasionally found in the feldspar. It is black, opaque, and highly magnetic, and is usually allotriomorphic, but occasionally presents an approximation to definite crystalline outline. As shown by the calculation of the analysis of the rock, this iron ore contains a considerable percentage of titanic acid.

Sphene is not found in more than one-half of the specimens examined. When present it is not very abundant and usually occurs as well-defined wedge-shaped crystals, often of considerable size.

In the accompanying table analyses are given of the normal essexite which forms the greater part of Mount Johnson, and of the finer-grained olivine-bearing variety of the same rock found at the summit of the mountain. For purposes of comparison there is presented in the same table the analysis of the essexite from Shefford mountain, which belongs to the same Monteregian province, together with analyses of the original essexite from Salem, Mass., and of allied rocks from two other localities. A partial analysis of the transitional rock between the essexite and the pulaskite of Mount Johnson is also given.

For the analysis of the Mount Johnson essexite (No. 1) as well as for that of the associated pulaskite, which is given below, I am indebted to Professor Norton-Evans, while the analysis of the olivine-bearing variety of the essexite (No. 2) was made for me by Mr. M. F. Connor. The methods recommended by Hillebrand and employed in the very accurate, analytical work carried out in the laboratory of the United States Geological Survey were followed by both analysts and every precaution was taken to insure accuracy.

	I	II	III	IV	V	VI
SiO_2	48.85	48.60	53.15	46.99	47.67	50.40
TiO_2	2.47	2.71	1.52	2.02	...	1.17
Al_2O_3	19.38	17.01	17.64	17.04	18.22	....
Fe_2O_3	4.29	3.09	3.10	2.56	3.05	5.58
FeO	4.04	6.41	4.65	7.56	3.85	
$NiO + CoO$	not det.	0.05	not det.	not det.	....	not det.
MnO	0.19	0.15	0.46	trace	0.28	0.77
MgO	2.00	3.06	2.94	3.22	6.35	....
CaO	7.08	7.30	5.66	7.85	8.03	6.77
BaO	....	0.08	0.13	none	...	...
Na_2O	5.44	5.05	5.00	6.35	4.03	6.24
K_2O	1.01	2.56	3.10	2.02	2.07	2.56
P_2O_5	1.23	1.11	0.65	0.04	....	0.09
Cl	not det.	not det.	0.07	....	....	....
H_2O	0.68	0.95	1.10	0.65	3.82	....
Total	99.36	100.02	99.84	99.60	100.15	

I. Normal essexite (andose), Mount Johnson, Quebec.

II. Olivine-bearing essexite (essexose), Mount Johnson, Quebec.

III. Essexite (akerose), Shefford mountain, Quebec, (*American Geologist*, 1901, p. 201), (with CO_2 0.39 and SO_3 0.28).

IV. Essexite (essexose), Salem Neck, Salem, Mass. (Washington, JOUR. GEOL., 1899, p. 57).

V. Theralite, Elbow Creek, Crazy mountains, Montana.

VI. Rock forming transition from essexite to pulaskite, Mount Johnson, Quebec. (Partial analysis. The iron present is all calculated as FeO.)

The analyses (Nos. 1 and 2) of the two varieties of the essexite from Mount Johnson can be readily calculated out so as to show the quantitative mineralogical composition of the rocks.

The calculation of the *mode*[1] — or relative proportion of the minerals actually present gives the following result:

[1] *Quantitative Classification of Igneous Rocks* (*C. I. P. W.*) (University of Chicago Press, 1903), p. 147.

	Essexite (Analysis 1) Mount Johnson		Olivine Essexite (Analysis 2) Mount Johnson	
Albite	36.75		29.14	
Anorthite	20.23	66.45	13.11	54.79
Orthoclase	9.47		12.54	
Nepheline	3.99	4.77	11.12	11.90
Kaolin	.78		.78	
Pyroxene		6.29		12.22
Hornblende		7.05		2.30
Biotite		2.04		4.08
Olivine		none		2.84
Magnetite	5.68	9.53	3.94	8.41
Ilmenite	3.85		4.47	
Apatite		2.68		2.59
Water (hygr.)		.58		.85
		99.39		99.98

In the case of No. 1 the percentage mineralogical composition given expresses exactly the chemical composition of the rock, except that it requires 0.06 per cent. of FeO in excess of that shown in the analysis. In No. 2 the agreement is complete.

The calculation further demonstrates that the plagioclase in the case of No. 1 is a trifle more basic, and in the case of No. 2 a little more acid, than $Ab_2 An_1$, which as has been stated, is shown by the optical character and by the specific gravity of the feldspar to represent its average composition in these rocks. The amount of orthoclase recognized in thin sections also appears as mentioned in the description of the rock. The nepheline is in places somewhat altered to a mineral resembling kaolin. The small percentage of kaolin shown by the calculation has therefore been added to the nepheline in extending the table.

In order to fix the position of these rocks in the excellent system of classification recently elaborated by Messrs. Cross, Iddings, Pirsson, and Washington, and to determine the name which should be given to these rocks, if their precise character is to be designated, it is necessary to calculate their *norms*. These have been found to be as follows :

	No. 1			No. 2		
Albite		35.63	69.82		28.02	57.30
Anorthite		23.07			14.23	
Orthoclase		11.12			15.05	
Nepheline			5.40			11.83
Diopside	$34 CaO . SiO_2$ —	3.94	7.56	$53 CaO . SiO_2$ —	6.15	12.03
	$7 FeO . SiO_2$ —	.92		$18 FeO . SiO_2$ —	2.38	
	$27 MgO . SiO_2$ —	2.70		$35 MgO . SiO_2$ —	3.50	
Olivine	$6 FeO . \frac{1}{2} SiO_2$ —	.61	2.22	$21 FeO . \frac{1}{2} SiO_2$ —	2.14	5.08
	$23 MgO . \frac{1}{2} SiO_2$ —	1.61		$42 MgO . \frac{1}{2} SiO_2$ —	2.94	
Magnetite			6.26			4.41
Ilmenite			4.71			5.01
Apatite			2.68			2.59
Water			.68			.95
				BaO = .08, Excess FeO = .07		.15
			99.33			99.35

No. 1 thus takes the following position in the classification in question:

Class II, dosalane.
Order 5, germanare.
Rang 3, andase.
Subrang 4, andose (grad = polmitic).

Its precise designation would be *nepheline-bearing grano-andose* or in some cases *nepheline-bearing tracho-andose*.

No. 2, however, belongs to the next order and is domalkalic. Its positi is as follows:

Class II, osalane.
Order 6, norgare.
Rang 2, essexase.
Subrang 4, essexose (grad = prepolic).

It would therefore be termed a *nepheline-bearing grano-essexose*. It is therefore seen that the essexite from the central portion of Mount Johnson (No. 2) is practically identical in character and composition with the essexite of the original locality at Salem, Mass. (Analysis IV), while the outer andose is poorer in nepheline and has a somewhat larger proportion of lime as compared with the alkalies.

The proportions of the several minerals present in thin sections of the specimens analyzed were then determined by the system of diametral measurements proposed by Rosiwal.[1] In

[1] *Verhd. K. K. Geol. Reichsanst.* (Wien, 1898), p. 143.

each case over 500 average diameters were measured instead of 100, which latter number Rosiwal considers to be sufficient. The measurements were, however, confined to a small number of thin sections, namely two in the case of No. 1, and four in the case of No. 2, it being considered advisable to use only sections cut from the actual specimen from which the material for analysis was taken. The results obtained were as follows:

	No. 1		No. 2	
Feldspar	63.77	per cent	64.06	per cent
Nepheline.	6.12	"	6.16	"
Pyroxene	9.26	"	13.60	"
Hornblende..	8.06	"	1.29	"
Biotite	2.11	"	1.07	"
Olivine.	[illegible]		1.30	"
Iron Ore	8.56	"	8.10	"
Apatite...	2.12	"	1.29	"
	100.00	"	99.07	"

In the case of No. 1 the results are substantially the same as the calculated *mode* except that there is about 3 per cent. more pyroxene and a correspondingly smaller proportion of feldspar. This relatively high proportion of pyroxene is unusual, the examination of thin sections of the rock for various parts of the mountain showing that, as has been stated above, and as is shown also by the calculation of the *mode* of this specimen, there is usually a preponderance of hornblende over pyroxene. In the case of No. 2 the chief difference between the values measured and the calculated *mode* lies in the relatively higher proportion of feldspar and lower proportion of nepheline in the former. In this rock, however, it is very difficult to distinguish the nepheline from the feldspar in every case. These discrepancies indicate that in applying Rosiwal's method to comparatively coarse-grained rocks such as these, especially if there be any tendency to irregularity in composition a considerable number of thin sections should be employed in order to obtain a true average of the rock as a whole.

For purposes of comparison the analysis of the essexite from Shefford mountain (No. III) has been reduced to its normative form and the position of the rock in the Quantitative classification determined. It is found to be as follows:

Class II, dosalane.
Order 5, germanare.
Rang 3, monzonase.
Subrang 4, akerose (grad = polmmic).

It thus, in composition, occupies, in a manner, a middle place between the essexose and andose of Mount Johnson.

THE PULASKITE.—This soda-syenite which, as above mentioned, forms the outer zone of the mountain, girdling the essexite, is less abundant than the latter and differs greatly from it in appearance. This difference is due chiefly to the fact that it is much lighter in color, being pale-yellow or buff instead of dark-gray, the lighter color being due to the very small proportion of iron-magnesia constituents present and the marked preponderance of the feldspars. The rock also has a more massive structure, the fluidal arrangement of the constituents often met with in the essexite being absent, and it weathers in a somewhat different manner. It possesses, moreover, a species of porphyritic structure, owing to the development of the feldspar in two forms: first, as stout prisms, up to 10^{mm} in diameter, which are light-gray in color and very abundant; and, secondly, in the form of smaller laths of a yellow or buff color which, in association with the iron-magnesia and other constituents, form a sort of groundmass in the rock.

The constituent minerals of the rock are biotite, hornblende, (pyroxene), soda-orthoclase, nepheline, sodalite, apatite, magnetite, and sphene. The darker constituents are identical in character with those occurring in the essexite, and therefore do not require to be described again. Not only are they as a class much less abundant in this pulaskite, but the mica here preponderates, being the prevailing iron-magnesia constituent, while the hornblende is much less abundant and the pyroxene is entirely absent. It may be noted, however, that the hornblende sometimes possesses the greenish tint referred to as occasionally seen about the borders of the hornblende individuals in the essexite, indicating probably that, the pulaskite magma being richer in soda, the hornblende crystallizing out of it has a tendency to take up this element more abundantly.

The feldspar in the pulaskite, as has been mentioned, occurs in part as stout prisms and in part as smaller laths. The latter usually have a somewhat cloudy appearance under the microscope, probably owing to incipient alteration. The larger feldspars are what is commonly described as soda orthoclase. When examined under the microscope they are seen to be composed of very minute intergrowth of two, and in some cases perhaps even of three, different feldspars — causing them to present between crossed nicols a mottled appearance. These several feldspars have somewhat different indices of refraction, and frequently under a high power, where two are present, one of them can be seen to possess a very minute polysynthetic twinning, while the other is untwinned. The relative proportion of the several feldspars present differs in different grains. The individuals as a whole occasionally present the form of carlsbad twins but usually have the appearance of simple crystals, and Professor Rosenbusch, to whom sections of the work were submitted, considers the feldspars composing them to be microcline, and in part microcline-microperthite, with probably some anorthoclase.

The specific gravity of these phenocrysts was determined in the case of two hand specimens of the pulaskite from different parts of the mountain. In the first of these three specimens of the feldspar were found to have specific gravities of 2.62, 2.609, and 2.603, respectively; while in the second, five specimens of the feldspar were selected and found to have specific gravities lying between orthoclase and albite, which bears out the results of their microscopic study.

The smaller lath-shaped feldspars, although more frequently composed of a single species, often show an intergrowth of two feldspars, as described in the case of the phenocrysts. Separations of the constituents of several species of the rock by means of Thoulet's solution show that these smaller feldspars have a somewhat lower specific gravity than the phenocrysts. Thus, while the specific gravity of the phenocrysts lies between 2.591, and 2.62, that of the smaller feldspars is between 2.591 and 2.56; that is to say, the smaller feldspars approach more nearly to pure orthoclase in composition. They consist chiefly of minute intergrowths of orthoclase with albite, or of either of these with microcline or anorthoclase. No lime-soda feldspar could be recognized in any specimen of the rock.

Nepheline and sodalite.—These minerals are quite subordinate in amount, although they are seen in nearly every thin section. Both minerals present the same characters and occur in the same way as in the essexite, lying chiefly in the corners between the other constituents being penetrated by the latter, but also occurring as inclusions in the feldspar. They are, as a general rule, much altered to the same decomposition product seen in nephe-

	VII	VIII	IX	X	XI	XII
SiO_2	57.44	59.06	65.41	56.45	59.01	60.03
TiO_2	0.97	0.66	0.16	0.29	0.81	.
Al_2O_3	19.43	19.12	16.96	20.08	18.18	20.76
Fe_2O_3	1.69	1.85	1.55	1.31	1.63	4.01
FeO	2.70	1.73	1.53	4.39	3.65	0.75
MnO	0.25	0.49	0.40	0.09	0.03	trace
MgO	1.16	0.65	0.22	0.63	1.05	0.80
CaO	2.66	2.24	1.30	2.14	2.40	2.62
BaO	not det.	.12	none	.....	.08	.....
Na_2O	6.48	6.08	5.95	5.61	7.03	5.96
K_2O	5.28	4.01	5.36	7.13	5.34	5.48
P_2O_5	0.60	0.14	0.02	0.13	trace	0.07
SO_3	not det.	0.08	0.06	.....	.....	.....
Cl	trace	0.14	0.04	0.43	0.12	.....
H_2O	1.03	1.10	0.82	1.51	0.50	0.59
	99.69	100.17	99.86	100.10	99.98	101.07

VII. Pulaskite (laurvikose), Mount Johnson, Quebec.

VIII. Pulaskite (laurvikose), Shefford mountain, Quebec. (*American Geologist*, 1901, p. 211.)

IX. Nordmarkite (nordmarkose), Shefford mountain, Quebec. (*Ibid.*, 1901, p. 209.)

X. Sodalite syenite, Square Butte, Montana (differentiation product of shonkinite).

XI. Umptekite, Red Hill, Moltonboro, New Hampshire.

XII. Pulaskite, Fourche mountain, Arkansas (original locality).

line in the essexite and which is, as has been mentioned, either kaolin or muscovite. Probably both are present.

Apatite is present in considerable amount and in the form of perfect crystals, occurring chiefly in the mica, hornblende, and sphene.

The *iron ore* and *sphene* present the same characters as in the case of the essexite, but the latter mineral is relatively more abundant than in that rock.

An analysis of this pulaskite is given in the accompanying table together with analysis of the pulaskite and the nordmarkite of Shefford mountain described by Dresser. Analysis of three allied rocks from other localities are added for purposes of comparison.

The *mode* of the Mount Johnson pulaskite (No. VII), calculated from the analysis given above, is as follows:

Albite - - - - -	48.73	
Anorthite - - - - -	3.06	74.03
Orthoclase and microcline	22.24	
Nepheline - - - - -		2.56
Kaolin - - - - - -		4.96
Hornblende - - - - -		5.08
Biotite - - - - - -		6.29
Magnetite - - - - -	1.86	2.77
Ilmenite - - - - - -	0.91	
Sphene - - - - - -		2.35
Apatite - - - - - -		1.34
Water (hygroscopic) - - -		0.30
		99.68

This proportion of the various minerals expresses exactly the chemical composition of the rock as presented by the analysis, except that a very small excess of silica, amounting to 0.06 per cent., is required.

The calculation shows clearly the fact, ascertained by the study of the thin sections of the rock, that a considerable percentage of sphene is present, a mineral which does not occur at all in the essexite.

The anorthite is probably in combination with the other feldspathic constituents in the form of anorthoclase. The calculation also brings out clearly a point already mentioned, namely, that in this rock the nepheline is much more highly altered than in the essexite, as shown by the amount of kaolin present. This kaolin, however, is not entirely derived from the alteration of the nepheline, but appears as a haze all through the smaller feldspars, and hence in the extension of the results should be assigned in part to the nepheline and in part to the feldspar. It is of course impossible to measure the amount of kaolin present by Rosiwal's method, occurring as it does distributed through the sections in the form of extremely minute individuals. If, however, the amount of nepheline given by the Rosiwal measurement be correct, namely 4.40 per cent.—and this of course includes both the unaltered mineral and that filled with decomposition products—then 1.84 per cent. of the kaolin has been derived from the alteration of the nepheline. There will thus remain 3.12 per cent. of the kaolin which has been derived from and measured up with the feldspar. If this amount be added to the feldspar found by calculation, it will increase the proportion present to 77.15 per cent., which is within 0.09 per cent. of the percentage of feldspar obtained by the Rosiwal measurement.

The *norm* of the pulaskite is found to be as follows:

Albite		50.30	
Anorthite		9.73	85.61
Orthoclase		25.58	
Nepheline			2.56
Olivine	$2MgO.SiO_2$	2.03	2.54
	$2FeO.SiO_2$	0.51	
Corundum			0.41
Magnetite			2.55
Ilmenite			3.80
Apatite			1.34
Water			1.03
			99.84

Its position is, therefore, as follows:

Class I, persalane.
Order 5, canadare.
Rang 2, pulaskase.
Subrang 4, laurvikose.

It should thus be termed a *grano-laurvikose* or possibly, in view of its somewhat porphyritic structure, a *granophyro-laurvikose*. The proportions of the several minerals present, or *mode*, as determined by Rosiwal's method were as follows:

Feldspar	77.21	per cent.
Nepheline	1.40	"
Hornblende	5.37	"
Biotite	7.08	"
Iron ore	1.81	"
Sphene	3.29	"
Apatite	.81	"
	100.00	

For purposes of comparison the analysis of the pulaskite (No. VIII) and of the nordmarkite (No. IX) of Shefford mountain were calculated into their respective *norms* and the position of these rocks in the new system of classification determined. The pulaskite (No. VIII) is found to have the following position:

Class I, persalane.
Order 5, canadare.
Rang 2, pulaskase.
Subrang 4, laurvikose.

The nordmarkite (No. IX), however is peralkalic and must be classified as follows:

Class I, persalane.
Order 5, canadare.
Rang 1, nordmarkase.
Subrang 4, nordmarkose.

It, however, lies just on the line between nordmarkose and phlegrose, and might thus be best termed a nordmarkose-phlegrose.

It is thus seen that the rocks from Mount Johnson and from Shefford mountain which, following Rosenbusch's classification, have been called pulaskite, and which in this new scheme of classification are pulaskase, are almost identical in composition with one another and with the Norwegian laurvikite, and the nordmarkite of Shefford mountain is very close in composition to the nordmarkose of the original Scandinavian locality.

Diagrams showing the composition of these several rocks are presented in Fig. 4.

THE TRANSITIONAL ROCK. — As has been mentioned, there intervenes in Mount Johnson between the pulaskite border and the central mass of essexite a transitional zone consisting of a rock which is dark in color and thus resembles the essexite, but which is characterized by the presence of large porphyritic feldspars sometimes as much as two inches in length, of peculiar form scattered through it and often arranged with their larger axes in the same direction, thus giving a fluidal appearance to the rock. This rock contains a large proportion of the same iron-magnesia minerals, more especially the hornblende, found in the essexite, and passes over gradually into this rock. Its passage into the pulaskite is rather more abrupt and is marked chiefly by the almost entire disappearance of the dark-colored constituents above mentioned. There is, however, a continuous transition or passage from the pulaskite through this intermediate rock into the inner essexite of the mountain.

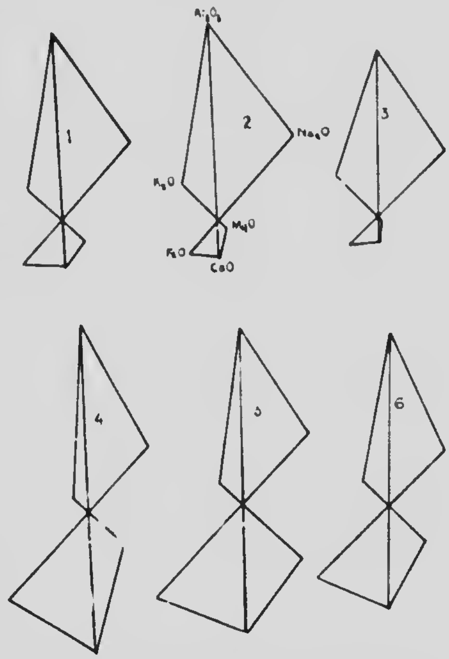


FIG. 4.—Diagrammatic representation of the chemical composition of the several rocks described.

No. 1. Laurvikose — Mount Johnson.
No. 2. Laurvikose — Shefford mountain.
No. 3. Nordmarkose — Shefford mountain.
No. 4. Andose — Mount Johnson.
No. 5. Essexose — Mount Johnson.
No. 6. Andose — Shefford mountain.

This transitional rock is composed of the same minerals as the essexite with the exception of the feldspar, which consists in part of the soda-orthoclase characteristic of the pulaskite, and in part of the plagioclase (in this case oligoclase) which forms the feldspathic element of the essexite. It is thus in mineralogical composition intermediate between these two rocks, although, as above mentioned, being rich in the dark-colored constituents, it more closely resembles the latter.

The large feldspars have frequently a peculiar crystalline form giving to the mineral, when broken across, a perfect hexagonal outline. The six faces represented in this form are apparently T, L, and M. The crystals hold many little inclusions of pyroxene, biotite, hornblende, magnetite, sphene, and nepheline, often regularly arranged so as to give a zonal structure to the feldspar individual. The specific gravity of twelve small fragments of the feldspar of these large crystals, collected from a locality on the southern side of the mountain and as free as possible from all inclusions, was determined. The specific gravity of nine of these lay between 2.59 and 2.607, while that of the other three was between 2.625 and 2.628. This shows the feldspar in the former case to be identical with that of the pulaskite, while in the latter three the specific gravity lies between that of albite and oligoclase. The somewhat greater specific gravity in this case may be due in part to inclusions of other minerals. A separation of the constituents of the rock shows, however, that, as above mentioned, a considerable amount of oligoclase is really present. The feldspar individuals, both great and small, usually show in thin sections the mottled character due to the intergrowth of different species, described in the pulaskite. A partial analysis of a specimen of this intermediate rock, from the south side of the mountain, is given in the accompanying table of analyses (No. VI), on page 265. As will be seen, in chemical composition as well as in mineralogical character, it occupies a position intermediate between the essexite and the pulaskite, occurring on either side of it, thus representing an intermediate zone in which the differentation was not quite completed. It is, however, much more nearly allied to the essexite, being alkalicalcic and dosodic, and although in the absence of a complete analysis or detailed measurements its position in the new classification cannot be determined with absolute certainty, there is very little doubt that it also, like the essexite adjacent to it, is an andose.

DYKES.—A feature in connection with Mount Johnson, and one possibly connected with its somewhat peculiar structure, is the almost entire absence of dykes. These were found only in two places, and in both cases the dykes were small in size. The first of these localities is on the northeastern margin of the intrusion, where the dyke occurs in association with and probably cutting the hornstone. It was found as large angular blocks in the heavy maple bush which here covers the slope of the mountain, but is undoubtedly in place in the immediate vicinity. The rock is very dark gray in color and very fine in grain, and belongs to the camptonites. It has a porphyritic structure, the very numerous phenocrysts consisting of hornblende and pyroxene. The hornblende phenocrysts are deep-brown in color and strongly pleochroic, the mineral being the same basaltic hornblende described in the essexite. The pyroxene of the phenocrysts is pale purplish in color and shows a marked dispersion of the bisectrices. Both minerals have very perfect crystalline forms. The plagioclase of the rock is very basic in character, as shown by its high extension. The rock resembles very closely certain occurrences found on Mount Royal. The size of this dyke is not known, but it probably has not a width of more than a foot or two. The other dykes occur on the southeastern slope of the mountain by the side of the road leading down from the quarries here. At this locality there are four small dykes, the largest only a foot in width, cutting the essexite. These are all very fine in grain and much decomposed, but represent two varieties of rock. Two of the smallest are composed of a camptonite consisting of a groundmass of brownish hornblende and plagioclase, with lath-shaped plagioclase phenocrysts. The other two dykes consist of a rusty weathering rock, made up of feldspar laths and a mass of pseudomorphs of limonite after some prismatic mineral, probably either ægerin or arfvedsonite. Professor Rosenbusch considers it to be a highly altered tinguaite or sölvsbergite, probably the latter.

The several dykes, while small and unimportant in themselves, are of interest in that they present the petrographical types regularly associated with the alkaline rich intrusions of the class represented in Mount Johnson.

The Structure of Mount Johnson.—The structure of the mountain and the character of the rocks composing it also throw some light on the question as to where the differentiation took place. In course of conversation with the foreman of one of the quarries in the essexite on the flank of the mountain, the writer was informed by him that Mount Johnson consisted of three layers of horizontal rock; a fine grained one on top, below which

FIG. 5.—Quarry in andose, Mount Johnson, showing vertical flow structure on right.

was the coarser-grained rock of the quarry, and beneath this a spotted variety. Each of these layers, he considered, went through the mountain horizontally and could be seen outcropping at their respective levels on every side. The three rocks referred to were, as will be recognized, the fine-grained essexose, the andose, and the transitional rock below the latter, respectively. The pulaskite zone he had not noticed, it being at the base of the mountain and in many places more or less covered with fallen blocks and talus. If this were the true interpretation of the structure, the mountain would have to be considered as the remnant of a laccolite which had been intruded between the horizontal Silurian strata and which had subsequently been almost entirely removed by peripheral denudation. This has been shown to be the true explanation of the origin of some of the occurrences, formerly supposed to be intrusive stocks, in the western portion of the United States, and it was at first considered as a possible explanation of the origin of Mount Johnson. A careful examination of the mountain, however, shows that such an explanation of its origin is untenable, and that it is a true neck, due to the filling up of a nearly circular perforation in the horizontal strata of the plain, by an upward moving magma.

The evidence of this is to be found in the direction of the banding or fluidal arrangement of the crystals in the essexite already referred to and shown in Fig. 5. This fluidal arrangement is seen in most large exposures of the essexite and with especial distinctness in the great faces of this rock exposed in the quarries on the mountain side, and it is always vertical, showing that the movement of the rock was upward through the pipe, and not outward and horizontally over the pulaskite, as it would have been in the case of a laccolite. Furthermore, in several cases when the fluidal arrangement is very distinct and has a somewhat banded character, as shown in Fig. 6, due to the alternation of somewhat more feldspathic portions of the rock with others richer in iron-magnesia constituents, a strike can be made out on horizontal surfaces, and this strike curves around the mountain, following its marginal outline, as shown in the map, Fig. 2.

It is thus clear that Mount Johnson is a neck in its most typical form. A cross-section of the mountain is shown in Fig. 7. The opening occupied by the intrusion was in all probability formed by the perforation of the horizontal shales at this point by the explosive action of the steam and vapors preceding the eruption proper, as it presents exactly the features reproduced by Daubrée in his highly suggestive experiments on the penetrating action of exploding gases. It is, in fact, what he terms a *diatrème*.

Des perforations aussi remarkables, tant par leurs formes que par les communications qu'elles ont établies avec les profondeurs du sol, constituent, parmi les cassures terrestres, un type assez nettement charactérisé pour mériter d'être distingué par une dénomination précise et cosmopolite. Le nom de diatrème rapelle l'origine probable de ces trouées naturelles, véritables *tunnels verticaux*, qui se rattachent souvent, comme un accident particulier, aux cassures linéaires, diaclases et paraclases.[1]

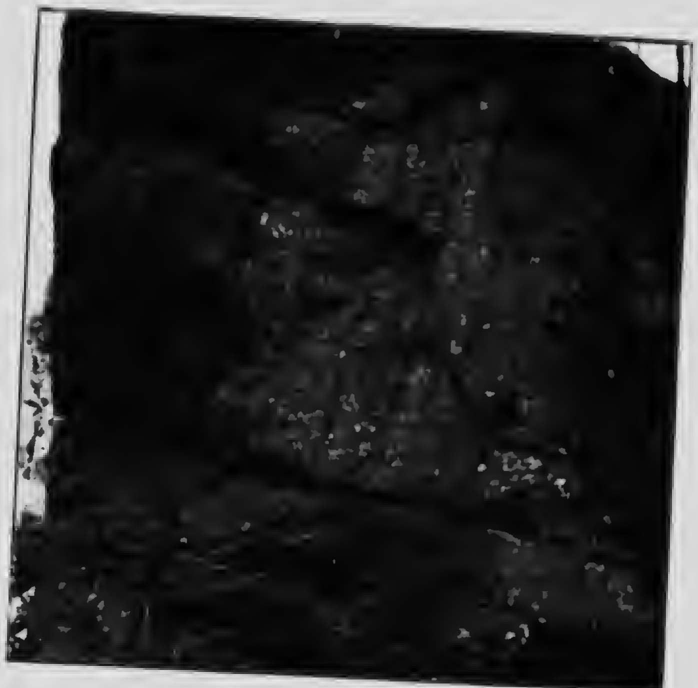


FIG. 6.—Andose in quarry on Mount Johnson, showing vertical flow structure.

The occurrence is one which presents a close resemblance to the remarkable volcanic necks recently described by Sir Archibald Geikie[2] in East Fife, and also to those described by Branco,[3] in Würtemberg. Mount Johnson, however, is a neck occurring

[1] "Recherches expérimentales sur le rôle possible des gaz à hautes températures doués de très fortes pressions, etc.," *Bull. de la Soc. Géol. de France*, 3e série, tome XIX (1891), p. 328.

[2] *The Volcanic Necks of East Fife*. Glasgow: Hedderwich & Sons.

[3] *Schwabens 125 Vulcan-Embryonen und deren tufferfullte Ausbruchsrohren das grosste Gebiet ehemaliger Maare auf der Erde*. Tübingen, 1894.

in an area which has undergone much more extensive denudation since the time of the intrusion than in the cases above mentioned, and as a consequence of this the fragmental material which fills some, although not all of the necks referred to above, has been entirely swept away.

In view of the fact, then, that Mount Johnson is a neck or pipe of comparatively small sectional area, in which the differentiation is very complete, but in which the magma did not remain at rest, but was not long prior to final consolidation,

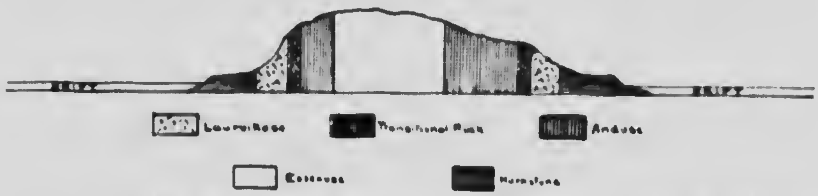


Fig. 7. Diagrammatic cross-section of Mount Johnson, showing the relation of the several rock types.

moving upward, it seems improbable that the marked differentiation of the magma into the several varieties described in this paper took place while the magma was in the pipe itself. The evidence points rather to the differentiation of the mass having already taken place in the reservoir of molten rock beneath, which was tapped by the pipe. If this be the case, it would seem that the upper and more acid portion of the magma, represented by the lighter pulaskite, had collected in the upper portion of the reservoir, and that the essexite formed a lower, more basic, and heavier stratum or part. When the passage to the surface was opened up, the pulaskite would first rise in it and, after a more or less long-continued flow, being followed by the essexite, would be pressed toward the circumference of the pipe, the more basic rock occupying the central portion of the passage, and the most basic variety, originally lower, would be found in the central axis of the neck. The fact that, while the essexite forms the mass of the intrusion, there is a zone of pulaskite about it, would seem to indicate that there had not been at this center of volcanic activity any very protracted outpouring of the essexite, since, had this been the case, it would seem probable that the pipe would have in time been cleared of the earlier pulaskite magma.

The interesting question of the succession of the eruption of the several magmas in this petrographical province, as well as the causes of their differentiation, can be more profitably discussed when the other centers of eruption have been more thoroughly studied. It is interesting to note the cumulative evidence in favor of differentiation as an explanation of the origin of these and similar groups of rocks, arising not only from the repeated association of the various members of the group at many centers in a single area like that described in the present paper, but also at centers widely separated from one another in different parts of the world. The occurrences described by Ramsay[1] in the Kola peninsula may be especially noted in this connection as closely allied to those of the Monteregian hills, a soda-syenite (umptekite) occurring about the margin of an intrusion of the nepheline-syenite which constitutes the *massive*, while theralite is also found as a differentiation product of the same intrusion.

The author desires to acknowledge his indebtedness in connection with this investigation to Miss Rosalind Watson, of Victoria, B. C., who, when a student at this university began the study of Mount Johnson; also to Professor Rosenbusch, Professor Iddings, and Professor C. H. McLeod for valuable aid during the course of the work.

FRANK D. ADAMS.

McGill University,
Montreal.

[1] *Das Nephelinsyenitgebiet auf der Halbinsel Kola.* Fennia 11, No. 2. Helsingfors, 1894.