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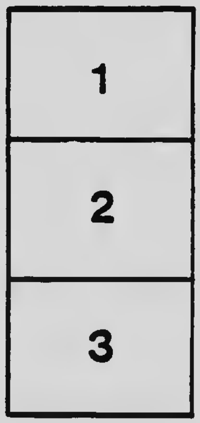
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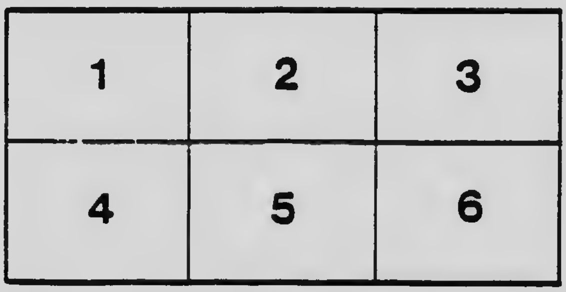
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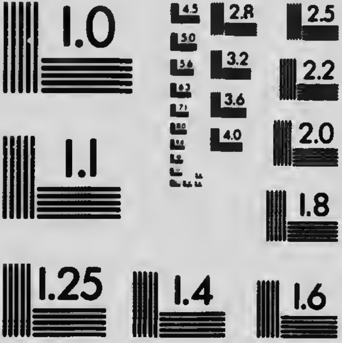

SHEFFORD MOUNTAIN AND BROME LAKE.

GEOLOGICAL SURVEY OF CANADA
ROBERT BELL, M.D., Sc.D., LL.D., F.R.S.

REPORT

ON THE

GEOLOGY AND PETROGRAPHY

OF

SHEFFORD MOUNTAIN

QUEBEC

BY

JOHN A. DRESSER, M.A.

OTTAWA
PRINTED BY S. E. DAWSON, PRINTER TO THE KING'S MOST
EXCELLENT MAJESTY
1902

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No 776

To Robert Bell, M.D., LL.D., Sc. D., F.R.S.,
Acting Director of the Geological Survey of Canada.

Sir,—I beg to submit a report on the Geology and Petrography of Shefford Mountain, Quebec, the field-work for which has been done chiefly under the auspices of the Geological Survey at intervals during the seasons of 1897-8-9. The accompanying map is based on the topographic survey of the late N. J. Giroux for the Montreal sheet of the Eastern Townships maps, published in Volume VII of the Annual Report of the Geological Survey of Canada, 1894, in connection with the report of Dr. R. W. Ells on the areal geology of the district.

My warmest thanks are due to Dr. F. D. Adams, Logan Professor of Geology at McGill University, for valuable aid and advice in many parts of the work; also to Mr. M. F. Connor, B.A. Sc., Radnor Forges, Quebec for three rock analyses.

I have the honour to be, Sir,
Your obedient servant,

JOHN A. DRESSER.

St. Francis College,
Richmond, Que., May 1, 1901.

REPORT

ON THE

GEOLOGY AND PETROGRAPHY OF SHEFFORD MOUNTAIN, QUEBEC

BY

JOHN A. DRESSER, M.A.

The broad valley of the St. Lawrence river, which crosses the southern part of the Province of Quebec in a north-easterly direction, separates the Laurentian highlands on the north from that part of the Appalachian system to the south, known as the Green mountains in Vermont, and as the Notre Dame, or Shickshock, range in the Province of Quebec. The valley is a nearly level plain, and in the western part of the province is about eighty miles in width. It is underlain by strata, which are often nearly horizontal in position and are of Palæozoic age, ranging from Cambrian to Devonian. In its topography, this region is sharply distinct from the undulating Laurentian which emerges from underneath it at the north-west, but is less definitely separable from the hilly country on the south-east, into which it gradually passes. Certain strata along the main axes of the Notre Dame mountains are now classed [illegible] pre-Cambrian, but the Palæozoic members become highly contorted in many places before these are brought into view. Topography.

Across this valley a single line of hills extends in a general easterly course at about the latitude of Montreal [illegible] These hills appear at intervals of ten to twenty miles, often ris[illegible] a height of a thousand feet or more, above the surrounding plain [illegible] conspicuous features of that part of the valley in which they [illegible] Their igneous origin and intrusive character have been long kn[illegible] They were thus described by Logan in the "Geology of Canada," [illegible] (p. 655): Monteregian Hills.

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*Annual Report Geol. Sur. Can., Vol. III (N.S [illegible]); Part J.

†In a recent communication upon the subject of [illegible] Johnson (Trans. Roy. Soc. Can. 1902), Dr. F. D. Adams has proposed the t[illegible] of "Monteregian Hills" to designate this series. A name for the series is an al[illegible] necessary convenience and that proposed seems most aptly chosen.—J. A. D.

Logan's description.

'The palæozoic strata of the district of Montreal afford a great variety of intrusive rocks, which may be classed under the heads of trachyte, phonolite, diorite and dolerite. These various rocks appear along a line of disturbance which is nearly transverse to the undulations of the Notre Dame mountains. Commencing at the hills of Brome and Shefford, which are nearly on the line dividing the eastern and western districts of palæozoic rocks, this disturbance may be traced for a distance of one hundred and eighty miles nearly westward, to the Lac des Chats upon the Ottawa. In this vicinity the undulation, which is more gentle to the eastward, gives place to a break in the strata.

'The most important of the intrusive masses appears along this line in the form of hills breaking through the Lower Silurian strata; and are as follows, beginning with the contiguous mountains of Brome and Shefford, and going westward: Yamaska, Rougemont, Belœil, Montarville, Mount Royal and Rigaud; the last being about ninety miles distant from the first *.

'A few miles to the south of Belœil is Mount Johnson or Monnoir, another intrusive mass; which, although out of the range of those just mentioned, apparently belongs to the same series. The mineral composition of these rocks varies greatly, not only for the different hills, but for different parts of the same one. Thus, Shefford and Brome mountains consist of granitoid trachyte; while the succeeding one of Yamaska, and Rigaud at the other extremity of the line, are partly of trachyte and partly of diorite. Monnoir and Belœil are made up of diorite; while Rougemont, Boucherville,† and Mount Royal consist in great part of dolerite; presenting, however, many varieties in composition and sometimes passing into pyroxenite. The dolerites of Rougemont and Mount Royal are cut by dykes of trachyte; similar dykes also traverse the dolerite of Yamaska, and may perhaps be connected with the trachytic portion of the mountain. It is probable, judging from some specimens from Rougemont, that the dolerite is there intersected by veins of diorite; some of which resemble that of Belœil and others that of Mount Johnson. Dykes both of trachyte and dolerite are also found traversing the sedimentary strata in many localities in the vicinity of these great eruptive masses.'

Shefford and Brome mountains.

* The recent investigations of Mr. LeRoy, (Bull. Geol. Soc. Am., 1900), show that Rigaud may belong to the Laurentians, which would thus shorten the line of intrusives, Mount Royal, the next undoubted member of the series being about fifty miles from Shefford.—J. A. D.

† or Montarville.

The mountains of Brome and Shefford, with which this series appears to end towards the east, are separated from each other by some four miles of stratified rock, and Yamaska, the next mountain of the series, is eleven miles distant from Shefford. Concerning the relative positions of these mountains Dr. Ells says: 'Brome and Shefford occur along the line of contact between the Cambro-Silurian and Cambrian rocks, while Yamaska mountain is situated on the line of fault between the Sillery division of the Cambrian and the Lower Trenton formation. It is probable that the Shefford and Brome extrusion is also along a fault line, the presence of which is not so clearly indicated as that on which Yamaska mountain lies, although the amount of dioritic material is much greater at Brome.' Position described by Dr. Ells.

The extreme length of Shefford, which is the smallest of these three mountains, is three and a half miles, its greatest breadth two and a half, and its area somewhat less than nine square miles. Extent.

The mean altitude of the surrounding plain is approximately five hundred feet above sea level,** but the mountain rises in two ridges from one thousand to twelve hundred feet higher. The intervening 'notch' between these ridges is, on the south and west sides, about seven hundred feet above the base of the mountain, or nearly twelve hundred feet above sea-level. Altitude.

The sedimentary strata which surround the igneous part of the mountain, consist of quartzites, conglomerates and light and dark gray slates. The last mentioned rocks are described by Dr. Ells as belonging to the Lower Trenton formation, while the others are referred by him to the Cambrian system. All these rocks strike in a N. N.E. direction and dip at varying angles; always, however, above 45° towards the W.N.W. They have a nearly vertical cleavage, which agrees in the direction of its strike with the stratification. Surrounding rocks.

Near the contact with the igneous portion of the mountain, the sedimentary rocks "pitch" or dip longitudinally away from it at high angles. They wrap around the base of the mountain, mantling it with a hardened contact zone, to a height of three hundred to a thousand feet above the plain, *loc. cit., varying with the amount of glaciation.

The mountain thus attests the enormous amount of erosion which the whole region has suffered, its present elevation above the surround- Relief due to erosion.

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* Annual Report Geol. Surv., Can. Vol. vii, (N.S.), p. 73 J.

** West Shefford station on the Canadian Pacific Railway, is 440 feet above mean sea-level. Can. Pac. Ry profile, P. Alex. Peterson Chief Engineer. The other elevations given are the means of several aneroid measurements from this station.

ing plain being evidently due to the greater resistance to denuding agencies that is offered by the igneous than by the little altered sedimentary rocks. For, in addition to the facts just cited, there is a large mass of black slate, similar to that which was said to be of Trenton age, on the highest ridge of the mountain above Knotts' corner. It is scarcely more altered than that near the contact at the base, and is penetrated by dykes from the underlying igneous rocks, which, in the area beneath it, are of two different ages of intrusion.

This slate covers an area of not less than a quarter of a square mile and its thickness near the head of Plamondon's wood slide was estimated at one hundred feet. From these facts, together with the entire absence of any tuff-like material, and the holocrystalline character of the igneous rocks, it is inferred that Shefford mountain is an uncovered laccolite rather than the denuded 'neck' of a once active volcano. This view is also corroborated by the occurrence of smaller patches of sedimentary rock in several other places on the igneous portion of the mountain.

A laccolite.

THE CONTACT.

Ektomorphic contact phenomena.

An approach to the contact of the sedimentary with the igneous rocks is generally well indicated in the former by the development of a rusty-brown colour. In the quartzite the alteration is comparatively inconspicuous, the zone of discoloration being never more than a few yards in width, while in the black slates the rusty colour and other evidences of local metamorphism are quite distinct at a distance of one hundred yards from the contact. Where they are especially altered the slates often resemble fine trap rocks so closely that their actual character cannot be ascertained without seeing a freshly fractured surface.

Along the actual contact they are commonly reduced to a 'gossan-like' mass resulting from the oxidation of the large amount of iron sulphides which have been developed in the slates by igneous metamorphism. These are usually in the form of pyrrhotite and are extremely oxidized.

Pyrrhotite.

These sulphides, where unaltered, are sometimes evenly disseminated throughout the rock, but at others are segregated in small masses, which on alteration produce rusty or brown spots on the weathered surface four or five inches in diameter, (plate iii.).

A specimen of the black slate was taken about two hundred yards from the contact with igneous rocks near Dounan's quarry. It is a dark steel-gray rock with a good slaty cleavage and shows a rusty colour along the joint planes. The specimen when taken was thought to be entirely unaffected by the intrusion of the mountain mass.

Altered slates.

On the sawn surface fine light gray lines are quite apparent, which were not previously noticed, and under the microscope these are found to be crystalline feldspar. The greater part of the dark-coloured layers consists of magnetite, with possibly a little graphite, and feldspar grains. Shreds of mica, generally colourless, are also present. Besides the light coloured, feldspathic bands, the rock contains numerous rounded spots also of a lighter colour. These are so small as not to be noticeable to the naked eye. They differ from the rest of the rock in showing no banded structure, the dark minerals which are in smaller grains being evenly distributed in them. The spots are therefore regarded as an incipient form of alteration which has evidently taken place since the foliation of the rock was well advanced, if not quite completed, and hence as probable contact phenomena. The light-coloured bands appear to be only miniature veins of feldspar, such as might occur in any part of the regionally altered rocks, and are not thought to be due to contact metamorphism.

Four specimens from the slate cap on the top of the mountain, which was referred to amongst the evidences of laccolitic structure, show that rock to consist of feldspar and brown mica with smaller amounts of magnetite and pyrite. In thin sections from specimens near the contact, the feldspar and mica are recrystallized and form a mosaic-like structure, the individual grains being bounded by polygonal outlines.

The oxidation of the pyrites in this mass, as in the contact previously described, gives much of the rock a reddish-brown colour.

Mica-schist.

A specimen from the light-coloured mica-schist near the base of the mountain, was taken about twenty yards from the contact near Beauregard's corner, is similarly discoloured in streaks by the alteration of pyrites which here occurs in cubical grains about $\frac{1}{16}$ inch in diameter. The feldspar is in part little altered from its original clastic character, while in other parts it is recrystallized, presenting much the same appearance as in the previous specimen. The mica here is in shreds, and some ferruginous matter that is present is in string-like forms following the cleavage of the rock.

Quartzite.

Quartzite comes in contact with the mountain for a short distance on the east side, and also on the west. It is best seen on the north side of the road leading from McCutcheon's corner to the mountain, where it contains a considerable amount of feldspar, and has rather the composition of quartzose sandstone. It is but slightly altered at a distance of fifteen yards from the contact.

Conglomerate

The principal sedimentary rock, besides those already mentioned, is a conglomerate, which may be seen at West Shefford, on the Central Vermont Railway. It consists of feldspar, biotite, quartz, augite, hornblende and magnetite in order of importance. The larger grains are comparatively few, and are either feldspar, which may be either plagioclase or orthoclase, or more commonly, quartz. No composite grains of larger size were distinguished. Much quartz appeared also in veins or irregular masses of secondary origin. But even these are often broken and faulted, sometimes showing very distinct strain shadows, the results of pressure subsequent to their deposition.

The dark minerals, of which biotite is the chief, in places, make up nearly half the rock. The structure is highly schistose, the larger nodules giving the appearance of a rather fine augen gneiss.

Few dykes

The sedimentary rocks are invaded by dykes from the main mass of the mountain in several instances, but on the whole somewhat rarely, while dykes, more recent than the mountain, cut both it and the sedimentary strata much more frequently. Fragments of the surrounding sediments are occasionally included in the margin of the igneous mass and the stratified rocks are much contorted in many places at the contact, yet on the whole the intrusion of the body of the mountain does not seem to have been accompanied by any very violent catastrophic action.

IGNEOUS ROCKS.

Kinds of igneous rock.

Three main classes of igneous rocks are easily distinguished in the field. The first is a rock of dioritic aspect, which weathers to a dark brown and shows a predominance of dark minerals. Detailed examination shows it to belong to the *Essexite* group. The second is almost wholly composed of rather coarsely crystalline feldspar. This is classed as *Nordmarkite*.

The third resembles it, but generally shows a somewhat porphyritic structure, and near the contact with the other rocks becomes still finer in texture and often assumes a greenish shade. It is *Pulaskite.*

Structural relations.

Their structural relations are clearly defined, each being the product of a separate irruption. The first is penetrated in many places by dykes of each of the other rocks, and the second by a large number of dykes of the third. The contacts of the different masses with one another can be seen and in all cases corroborate the evidence of the dykes. The second mass has generally been intruded along the former line of contact between the earlier igneous and the sedimentary rocks, although it also divides the former into two parts, while the third has been injected between the other two igneous rocks. These relations can be most easily seen by a reference to the accompanying map.

Essexite.

ESSEXITE.—This is a rather coarsely crystalline rock of granitic texture, dark-gray in colour and weathering to a dull brown. On a fresh fracture, feldspar is seen to be the most abundant of any one class of constituents, and by the aid of a pocket lens part of it can be seen to be striated by polysynthetic twinning and hence is triclinic.

Hornblende.

The most conspicuous of the dark minerals present is hornblende, which is of a black or dark-brown colour and varies considerably in amount. In some of the contact phases it makes up fully half of the rock, but in general it is quite subordinate in amount to the feldspar. In typical parts of the essexite it is also exceeded in amount by a light coloured variety of augite which it is difficult to discern in the rock by the naked eye. Brown mica is often closely associated with the hornblende, probably by intergrowth due to contemporaneous crystallization.

Feldspar.

A mechanical separation of a specimen of this rock (No. 179) plate iv, was made by Mr. O. E. LeRoy at the petrographical laboratory of McGill University by means of Thoulet's solution, and the following specific gravity determinations of feldspars were obtained. When the specific gravity of the liquid was reduced from 2·689 to 2·651, much feldspar fell; between 2·651 and 2·62, much feldspar both in clear and also in turbid grains; between 2·583 and 2·524, a smaller amount of feldspar, all turbid. There were no lighter constituents.

Specimens of the powder taken at 2·524, 2·62, and 2·651 were mounted in Canada balsam and ground for microscopic examination.

Orthoclase. The first shows no striation and in ordinary light is quite turbid. It is presumably all orthoclase. Of that which fell at 2·62, the clear grains are finely striated by polysynthetic twinning, to the plane of which the extinction is nearly parallel. They are oligoclase or andesine. The turbid grains of this weight are mostly composite, being made up of orthoclase and a heavier constituent, but a few are found to show albite twinning and an extinction angle of at least 30°. These are doubtless altered labradorite. The grains having a specific gravity between 2·651 and 2·689 showed the same differences in diaphaneity as those taken at 2·62, but the clear grains are here labradorite since the extinction angle on the twinning lamellae rises to 36°.

Oligoclase-andesine.

Labradorite.

These three feldspars may also be distinguished in the thin section, where the oligoclase-andesine, which is in the greatest amount, is seen to differ from orthoclase by twinning structure and from labradorite by its small angle of extinction, finer twinning lamellae and more allotriomorphous outline. The labradorite constitutes the largest and best formed of the feldspar crystals.

Microscopic features.

In thin sections from typical parts of the rock (specimens 179, 177, 174, 147, 146, 142, 141 *et al*) the minerals were found as follows in order of relative amount.

Essential constituents: Plagioclase, orthoclase, augite, biotite, hornblende.

Accessory constituents: Magnetite, sphene, apatite, quartz (rare); with leucoxene as a secondary constituent.

The structure is hypidiomorphic, and the order of crystallization, the normal one for plutonic rocks, that of decreasing basicity. The ferro-magnesian constituents enclose the usual basic accessories, apatite, sphene and magnetite, and are themselves generally of an earlier crystallization than the feldspars. Of the latter, the more basic plagioclase shows the strongest tendency to assume idiomorphic forms, while both it and the more acidic varieties of plagioclase are cemented together by orthoclase.

Augite.

The *Augite* is colourless, or of a light greenish-gray colour, and is without perceptible pleochroism. In polarized light, extinction takes place when the plane of either nicol bisects the angle of cleavage, which is nearly a right angle, in sections approximately parallel to OP, while the angle of extinction on the vertical axis rises to 45° as the zone of the clinopinacoid is approached.

Hornblende is trichroic, ranging in colour from deep chestnut to yellowish brown in ordinary light, its scheme of absorption being $\mathfrak{c}<\mathfrak{b}>\mathfrak{a}$. The greatest angle of extinction, $c \wedge \mathfrak{c}$, that was observed was 27°.

Biotite frequently encloses augite and seems to have generally crystallized later than that mineral. In some specimens (No. 147) an excellent micropoikilitic structure is thus produced, a number of augite individuals being set promiscuously in the larger crystals of biotite*.

Accessory constituents.

Sphene is an abundant accessory and occurs in characteristic wedge-shaped individuals, and also in larger columnar sections. It sometimes polarizes very brilliantly.

Iron is constantly present in small grains commonly enclosed in some of the ferro-magnesian silicates. It has the general characters of magnetite and the presence of leucoxene indicates its probable titaniferous character, as sphene was not observed to be altered to that mineral.

Apatite occurs in the usual forms and position, but in places becomes a very prominent accessory.

Chemical composition.

The structure and mineral composition of this rock ally it with the essexite group and the chemical analysis quite establishes this view. The variety and character of the feldspars, the features of the bisilicates and the prominence of apatite and sphene as well as the occasional occurrence of nepheline and sodalite in very subordinate amounts on the one hand, and quartz in even still smaller proportions on the other, indicate a magma intermediate in composition between diorite and theralite. The specimen for analysis (No. 179) plate iv, was taken from the more acid portion of the mass (Morriseau's quarry).

In its chemical composition this rock seems most nearly equivalent t[illegible] essexite from Rongstock, Bohemia, being in this case somewhat h[illegible]r in silica than the original essexite of Salem, Massachusetts. Its resemblance to the augite-diorite of Rosita Hills, Colorado**, especially to its orthoclase facies is also noticeable.

* 'On the use of the terms Poikilitic and Micropoikilitic in Petrography.'—G. H. Williams—The Journal of Geology, Vol. 1, No. 2.

** W. Cross, U. S., Geological Survey, 17th Annual Report, Part II, p. 291.

The analysis has been made by Mr. M. F. Connor, B.A.Sc., of Radnor Forges, Quebec.

—	I	II	III	IV	V
SiO_2	53·15	50·50	50·47	53·80	47·94
TiO_2	1·52	1·91	·51	·43	·20
Al_2O_3	17·64	17·64	18·73	20·13	17·44
Fe_2O_3	3·10	5·41	4·19	3·57	6·84
FeO	4·65	4·02	4·92	2·63	6·57
MnO	·46	—	·11	·29	—
CaO	5·66	7·91	8·82	5·60	7·47
BaO	·13	—	—	—	—
MgO	2·94	3·33	3·48	2·26	2·02
K_2O	3·10	3·02	3·56	4·49	2·79
Na_2O	5·00	5·52	4·62	5·20	5·63
P_2O_5	·65	·92	·10	·56	1·04
CO_2	·39	—	trace.	—	—
SO_3	·28	—	—	—	—
Cl	·07	—	trace.	—	—
H_2O	1·10	·45	·58	·90	2·04
	99·84	100·63	100·09	99·86	99·92

I. Essexite. Shefford (No. 179). Analysis by M. F. Connor.
II. " Rognstock, Bohemia. Quoted in 'Elemente der Gesteinslehre,' by Prof. Rosenbusch.
III. Augite-diorite (olivine facies), Mount Fairview, Rosita Hills, Colorado. This rock is also included in the Essexite group by Prof. Rosenbusch, loc. cit.
IV. Augite-diorite (orthoclase facies). Ibid.
V. Essexite. Salem Neck, Massachusetts.

CONTACT FACIES.

Endomorphic contact.

Along the original contact zone, the dark minerals are in increased amounts, and the texture of the rock becomes variable.

Couplands lake.

In a section exposed for a time during the construction of an aqueduct from Couplands lake to the town of Granby the contact facies were well shown. For forty yards from the contact the rock was fine-grained, and about one-half of it was made up of black hornblende. By a sharp transition, the rock then became exceedingly coarse for the next thirty yards, and the proportion of hornblende was somewhat increased. The hornblende crystals here are seldom less than half an inch in the smallest dimension. It next returned quite abruptly to the fine-grained type for two hundred and ten yards, when it passed more gradually into the normal type.

These phases are sometimes finer, at others coarser, than the texture of the main mass, but are marked by no other change of structure, unless possibly that the earlier crystallization of the hornblende than the feldspar is less apparent. (plate iii). The mineral composition, however, changes by a distinct increase in the amount of hornblende and decrease in augite, while the minerals sodalite* and nepheline* appear as accessary constituents. These are found chiefly in the coarser band that has been mentioned, but are not entirely confined to it.

Essexite of Massachusetts compared.

The rock then becomes practically identical in microscopic character with the essexite of the type occurrence at Salem, Massachusetts, which has been described by J. H. Sears, (Bulletin Essex Institute, 1891). Many of the finer specimens bear a strikingly close resemblance, both to the naked eye and in the thin section, to a type specimen for which I am indebted to Mr. Sears. These features are best shown in sections 102, 117, 144, 156, 202, 203, *et al*. One or two of these (202, 117) approach very closely to theralite.

Olivine, which is a variable constituent of the Massachusetts essexite, and also marks the more basic facies in the Rosita Hills, has not yet been found at Shefford, except at a single narrow dyke about one and a half inches in width, whose relations to the other igneous rocks could not be well ascertained. It is thought to belong to the later theralite dykes, but may be an offshoot from the essexite.

The breadth of the altered zone varies considerably, yet it was found wherever the contact could be well observed. Near Couplands lake, as noticed above, it was two hundred and eighty yards wide, and on the 'mountain road' at Lavigne's hill it is not less.

On the other hand at the southwest side of the mountain near Knott's corner, and also on the extreme opposite side, at Morriseau's quarry, no evidences of contact metamorphism could be seen at a distance of ten yards from the sedimentary rocks.

PEGMATITIC FORMS.

Pegmatite.

Another phase of this rock, whose occurrence could not be very well defined although it is quite extensive, as it appears continuously for half a mile in one direction, is distinguished by a very coarse texture and a singular reversal in the order of crystallization of the feldspar and hornblende.

*Both these terms are used throughout this sketch in the generic sense. The former mineral is sometimes a colourless variety in rounded or polygonal outlines with characteristic dust-like inclusions, and at others it occurs in strings between the feldspars and is blue in colour. In both cases it is isotropic. The latter is usually much decomposed and might be more precisely called elæolite.

Large individuals of hornblende, frequently measuring from two to three inches in each dimension, here enclose great numbers of small well formed feldspars, producing a very distinct poikilitic structure.

When light is reflected from the cleavage faces the hornblendes appear to be unbroken individual crystals, but on closer examination half their area is sometimes found to be occupied by the included feldspars. Hornblende is the chief of the dark minerals which can be seen on the fresh surface by the unaided eye, the large interspaces between the hornblende areas showing only white or light-gray feldspar. (plate v, fig. 3).

Under the microscope the crystals of feldspar in the dark portions of the rock are found to be set in large fields of hornblende without reference to the orientation of their host or of one another. They are often extremely well formed showing that they had reached their present degree of crystal growth before their inclosure by the later formed crystals of hornblende.

Character of crystallization.

This order of crystallization is in direct exception to that prevailing amongst eruptive rocks, viz. that of decreasing basicity, as defined in the 'laws' of Prof. Rosenbusch, according to which the ferro-magnesian minerals are formed in a cooling magma earlier than those of the feldspathic series. The principal exception to this law, is the case of the diabases in which augite crystallizes contemporanously with if not earlier than, feldspar. This, however, is commonly regarded as conforming to Rosenbusch's second law that the combinations of smaller amount in a magma crystallize out the earlier. Of the other ferro-magnesian silicates, augite appears in its usual position in relation of the feldspar, that is, distinctly earlier in crystallization, and enclosed by the biotite which is frequently intergrown with hornblende. The feldspar thus inclosed appears to be chiefly plagioclase and of the most basic character that is found in any of these rocks. The twinning lamellæ are broad and the extinction angles measured upon them rises to 40°, indicating basic labradorite or bytownite.

Bytownite. Apatite.

Apatite crystals are large and numerous, the mineral almost assuming the proportions of an essential constituent.

The mode of occurrence of this phase of the rock gives no discernible clue to the origin of the structure. It appears to be in segregated masses, certainly not in veins or with vein-like structure, and occurs both in the zone of contact and well removed from it, hence it cannot be regarded as a contact phenomenon. The nature of the rock precludes the idea of the structure being of secondary origin, hence it must be attributed to the conditions of the primary solidification of the rock, perhaps analogous to those under which pegmatite is formed. Pegmatite, which was formerly regarded as a more or less distinct rock species, is now generally considered as a possible varietal phase of almost any deep-seated rock, distinguished from the normal rock of its type by a more acid composition, usually by the presence of rare minerals, and certain structural differences, the whole being ascribed largely to the accumulation of water attendant upon the last stages of the progressive crystallization of a cooling magma confined under considerable pressure.* It is especially marked by peculiar mineral intergrowths produced by the nearly contemporaneous crystallization of minerals which usually form in succession, as quartz and feldspar granitic pegmatite, which produce the structure known as graphic granite, or in microstructure, as granophyre, or microgranite. In such cases the relation of quartz to feldspar in respect to their changed order of crystallization is quite analogous to that between feldspar and hornblende in the quartz-free basic rock of Shefford. Origin of pegmatite.

Basic or Amphibolitic Segregations.

Irregular patches of fine dark rock material occur frequently in the essexite. Hornblende can be distinguished in them with the unaided eye, and under the microscope is found to be the only constituent of importance besides plagioclase feldspar. There is a smaller amount of magnetite also present. The hornblende is generally green, and the feldspar always plagioclase. They have thus the composition of amphibolite, but have not the schistose structure which is a common though not an invariable characteristic of that rock. These masses appear in irregular string-like forms, ranging in size from a few inches in either dimension, to bodies commonly fifteen or twenty feet in length and perhaps a foot wide. One such mass was found which was exposed for over one hundred yards in length and about fifteen in breadth. It is intersected in many places by offshoots from the enclosing essexite in different directions giving it the appearance of an Amphibolite.

*W.C. Brögger.—'Die Mineralien der Syenitpegmatitgange der südnorwegischen Augit-und Nephelin-syenit,' I Theil, pp. 215-225, translated by N. N. Evans, Canadian Record of Science, Vol. VI, Nos. 1 & 2, pp. 33-46 & 61-71.

A. Harker.—'Petrology for Students,' Cambridge, 1897, p. 25.

G. H. Williams.—"On the Origin of the Maryland Pegmatites," XV. Rept. U. S. Geol. Survey, pp. 675-694.

A. E. Barlow.—Annual Report Geol. Surv. Can., Vol. X, (N.S.) part I, pp. 61-67.

W. O. Crosby and M. L. Fuller.—Technology Quarterly, Vol. IX, Dec. 1896, pp. 236-356.

inclined sediment invaded by the igneous rock. A block of this is shown in an accompanying figure, plate II. The mineral composition of these masses, however, seems to be so widely different from that of any of the sedimentary rocks of the locality as to make it a more probable theory of their origin that they are due to primary segregation. Yet it is one that requires still further evidence to be fully verified.

WEATHERING.

Disintegration.

The essexite is generally fresh in specimens obtained at any considerable depths, as in open quarries, yet the disintegration is strongly marked at a depth of eight feet in the excavations for the Granby waterworks, near Couplands lake, at a point where glaciation appears to have been quite as heavy as usual. Wherever decomposition is seen, calcite seems to be an important resultant product. This, together with the release of the potassium attendant on the breaking down of the orthoclase molecule (for orthoclase besides being the last to crystallize is the first to yield to disintegrating agencies) gives a considerable degree of fertility to the rock waste. Little of the virgin forest (conifers) remains, but a thrifty second growth (deciduous) is borne by a soil of angular grains of feldspar all but destitute of the slightest vestige of leaf mould. Roots can be seen penetrating the joint cracks of the rocks, and by their growth in size forcing the divisions of the rock apart. This healthy vegetation is, however, attributable in no small degree to the regular rainfall of the district, which amounts to about forty inches per annum. Pomological experts claim that the apples which are raised in great abundance on these eruptive hills are distinguishable by their flavour from those on the surrounding plain of stratified rock.

Effect on vegetation.

Spheroidal weathering.

The tendency of the essexite to weather into spherical forms by casting of concentric shells is well shown in the mountain road, near Lavignes brook. Here rectangular blocks have been largely reduced to rounded forms, leaving less surface in proportion to their volume.

Nordmarkite described by Logan.

2. NORDMARKITE.—The second variety of intrusive rocks in order of age is described by Logan (Geology of Canada, 1863, p. 656), as 'being made up in great part of a crystalline feldspar, with small portions of brownish black mica, or of black hornblende, which are sometimes associated. The proportion of these two minerals is never above a few hundredths, and is often less than one hundredth. The other mineral species are small brilliant crystals of yellowish sphene, and

others of magnetic iron, amounting together probably to one thousandth of the mass.'

It varies from a light-gray, almost white, to a fawn colour, and in some parts shows very noticeable amounts of the darker minerals, being often stained by oxide of iron to a light buff colour. Though not discernible by the naked eye, there is a nearly colourless augite present, which commonly equals the hornblende in amount, and is a rather more persistent constituent.

In thin sections of specimens that are considered typical, the essential constituents are feldspar and augite, the latter scarcely rising above accessory proportions (plate V, fig. 4). The feldspar in such specimens is wholly in the form of the interesting orthoclase-albite [illegible], microperthite. The following analysis shows its compositi[illegible] parison analyses are added of the original perthite fro[illegible], Ontar[illegible] [illegible]yptoperthite from Laurvik, Norway, and an [illegible] from the keratophyre of Marblehead, Massachusetts. N[illegible] and V are taken from the Geology of Canada, 1863, pp. [illegible] and 657 ; III is cited in 'Igneous Rocks of Arkansas,' Vol. II, [illegible] Survey, Arkansas, 1890, p. 60, from "Syenite-pegmatitgan[illegible] W. C. Brögger, p. 524 ; IV is given in Bulletin of the Museum of Comparative Zoology, Cambridge, Mass., Vol. XVI, p. 170, 'Keratophyre from Marblehead Neck,' J. H. Sears. Microperthite

The microphotograph numbered IV is from a specimen taken probably from the same exposures as that analysed under No. [illegible], while [illegible] the locality assigned to Nos. II and II*a* the only form of feldspar that could be found is also microperthite.

All the analyses are of feldspar only. In column [illegible] the approximate theoretical composition is given of a soda-potash feldspar [illegible] up of albite and orthoclase molecules in the proportion of 3:2.

ANALYSES. [illegible]

I. Feldspar—Shefford. Analysed by Hunt. Described by Logan.
II. Feldspar—Brome. " " " "
II*a*. Feldspar—Brome. " " " "
III. Kryptoperthite—Laurvik. " Gmelin " Brögger.
IV. Anorthoclase—Marblehead Neck. Analysed by Chatard. Described by Sears.
V. Perthite—Burgess. " Hunt. " Logan.
VI. Approximate theoretical composition of feldspar having the formula $Ab_3 Or_2$.

—	I	II	IIa	III	IV	V	VI
SiO_2	65·15	65·70	65·30	65·90	65·66	66·44	67·06
Al_2O_3	20·55	20·80	20·70	19·46	20·05	18·35	19·00
Fe_2O_3	....	....	....	·44	Trace.	1·00	
MnO	....	....	....	....	·13		
CaO	·73	·84	·84	·28	·67	·67	
MgO	....	....	*	....	·18	·24	
K_2O	6·39	6·43	*	6·55	6·98	6·37	6·93
Na_2O	6·67	6·52	*	6·14	6·56	5·56	7·00
H_2O	·50	·50	*	·12	† ·91 ‡1·28	·40	
	99·99	100.79	....	98·90	100·64	99·03	99·99

* Incomplete. † At 110°. ‡ Above 110°.

These analyses show clearly the chemical identity of the feldspars here compared. It is noticeable, however, that in minerals from Shefford and Brome, sodium is slightly in excess of potassium, while the proportions are reversed in all the others cited. An analysis of microperthite from pulaskite at Moultenborough, New Hampshire,* however, shows potassium to be slightly subordinate to sodium in amount.

Augite. The augite of this rock occurs in a few stout columnar crystals, and in ordinary light is either colourless, or has a pale greenish tint without perceptible pleochroism. It is frequently associated with smaller grains of magnetite, and both may enclose needles of apatite.

Hornblende. The hornblende is green in colour, never brown as in the essexite. Sections parallel to $\mathfrak{c}$ = deep-green ; $\mathfrak{b}$ = yellowish-green ; $\mathfrak{a}$ = straw colour. The scheme of absorption is accordingly $\mathfrak{c} < \mathfrak{b} < \mathfrak{a}$, and the maximum extinction angle that was observed, $c \wedge \mathfrak{c} = 26°$, practically the same as in the brown hornblende. It is sometimes more abundant than augite, and at others nearly or altogether wanting.

Biotite. The same may be said of the occurrence of biotite. This mineral is of a deep brown colour in ordinary light and polarizes in brilliant tints, probably indicative of a larger proportion of iron than usual in its composition.

Sphene. Quartz. Sphene frequently appears, and occasionally a few grains of quartz are seen, (Nos. 166, 118, 188). One of these shows an uniaxial cross and positive sign, thus clearly identifying it.

In structure the rock is coarsely granitic, but the absence of quartz in sufficient amount to form a cementing material for the other con-

* Quoted by Prof. Rosenbusch in 'Elemente de Gesteinslehre.'

stituents tends to render the rock friable. On exposure to the atmosphere it is easily disintegrated and in places is reduced to a loose mass of rectangular grains of feldspar for several feet in depth.

Norwegian rocks. Compared with some of the syenite types of southern Norway, which have been made classic by the work of Prof. W. C. Brögger, the resemblance is found to be a very close one. It probably approaches most nearly to gray nordmarkite from Christiania, from which the chief descernible microscopic difference is in the coarser intergrowth of the feldspar of the Shefford rocks. This resemblance in microscopic characters is also corroborated by the chemical composition as shown by the accompanying analysis by Mr. Connor.

Its similarity to the akerite type of Norway will also be noticed, as well as to that of a syenite from Mount Ascutney, Vermont.

——	I	II	III	IV	V
SiO_2	65·43	64·04	66·13	65·43	65·15
TiO_2	·16	·62	·74	·50	
Al_2O_3	16·96	17·92	17·40	16·11	20·55
Fe_2O_3	1·55	·96	2·19	1·15	
FiO	1·53	2·08		2·85	
MnO	·40	·23	·13	·23	
CaO	1·36	1·00	·81	1·49	·73
BaO	none	.....	.....	.....	
MgO	·22	·59	·04	·40	
K_2O	5·36	6·08	5·60	5·07	6·39
Na_2O	5·95	6·67	5·28	6·00	6·67
P_2O_5	·02	.....	.....	·15	
SO_3	·06	.....	.....	FeS_2 ·07; F ·08	
Cl	·04	.....	.....	·05	
H_2O	·82	1·18	1·22	·58	·50
	99·86	.....	.....	100·18	
Less O	0·09	.....	.....	·04	
	99·86	101·37	99·54	100·14	99·99

I. Nordmarkite—Shefford—(No. 166). Analysis by Connor.
II. " (gray) Tonsenas, near Christiania. Cited by Rosenbusch, 'Elemente der Gesteinslehre.'
III. Akerite—Between Thingshong and Fjellebuns, Norway. Cited as above.
IV. Syenite—Mount Ascutney, Vermont. Jaggar and Daly. Analysis by Hillebrand. U.S.G.S. Bull. 148.
V. Feldspar—Shefford—Already quoted.

CONTACT FACIES.

The contact zone of the nordmarkite is commonly distinguished by an increase in the dark minerals. Hornblende and biotite rise to

Endomorphic contact.

the importance of essential constituents, while the microscope shows larger and more numerous sphenes. Nepheline is also occasionally present around the periphery of the mass, though only in very subordinate amount. The feldspar becomes more finely laminated until the perthitic structure is all but lost, becoming discernible only in parts and under high power. This gives the mineral, which has otherwise the general aspect of orthoclase, a peculiar mottled appearance, answering apparently to the characters of kryptoperthite. A few grains of finely twinned plagioclase also appear.

Dounan's quarry.

In a mechanical separation made by Mr. LeRoy of a specimen (No. 145) from Dounan's quarry, about thirty yards from the contact, the feldspathic constituents fell at the densities 2·62, 2·583, and 2·566. The specific gravity of the specimen selected for analysis I of the feldspars, cited from the Geology of Canada, 1863, (p. 657) was 2·561. The darker colour which these rocks acquire in proximity to the contact often gives them a marked value for decorative purposes.

It is also noticeable that while the changes in the mineral constituents which characterize the endomorphic contact zone are such as to denote a more basic composition, yet certain dykes (No. 188, 135) radiating from the mass appear to be more acid than the normal rock. In them there is no increase of ferromagnesian constituents but rather an increase of quartz, a variation which has not been found in any other part approaching the contact.

Basic Segregations.

Basic masses.

The nordmarkite also contains dark masses in which the iron-magnesia minerals are prominent. The feldspar in these becomes finely granular and sometimes shows perthitic structure under high magnifying powers. The leading dark constituent is biotite, deep brown in colour with high double refraction. It is rather distinctly idiomorpl in form. Dark green hornblende with the usual pleochroism is abundant in these masses, but usually in small crystals. No augite appears.

The dark minerals together occupy rather less than half the rock, so that it is only by comparison with the light-gray, or fawn-coloured nordmarkite that these patches appear as dark-coloured rock.

In mode of occurrence they are similar to those found in the essexite already described, and are probably analogous to them in origin.

3. PULASKITE.—The third class of these eruptive rocks differs from nordmarkite principally in having hornblende as the characteristic bisilicate instead of augite, and in its structure, which though holocrystalline, is of a porphyritic trachytic character. It is rather variable in appearance, but is usually of a gray colour and fine texture, being too fine to admit of mechanical separation of the mineral constituents. It is often coated with a dark, almost black, oxide of iron which tends to obscure these features. Small crystals of black hornblende can be occasionally detected in the finer feldspathic groundmass, and coarse nodular masses, from six inches in diameter downwards, are commonly seen. Some of these are darker than the enclosing rock, while others are considerably lighter. In the marginal portions of this rock and in the numerous dykes which it sends off into the adjacent rocks it is more distinctly porphyritic. The groundmass in such cases assumes a dull greenish shade, due evidently to the increased proportions of the ferro-magnesian minerals, and small feldspar phenocrysts are plainly seen in it.

Pulaskite.

Crystallization variable.

A few specimens nearer the central portions of the mass show fine greenish specks which under the microscope are found to be ægerine-augite, while in others an occasional blue spot of sodalite is apparent to the unaided eye.

By the aid of the microscope, this rock is found to consist of feldspar, hornblende, augite, biotite, magnetite, sphene, sodalite and apatite. The first four, only, are in essential amounts, and the feldspar is by far the most important of all except in the endomorphic contact zone.

Mineral constituents.

The structure varies from coarsely trachytic in the central portion of the mass to porphyritic along the margin.

The phenocrysts include both orthoclase and plagioclase as well as hornblende and occasionally augite.

Of the feldspar phenocrysts, orthoclase is far the most abundant in the interior, while plagioclase largely predominates in the peripheral portions of the area and in the dykes. The increase of plagioclase at the expense of orthoclase in the phenocrysts seems to be analogous to that described by Cross* in the Game Ridge trachyte, the last member in the sequence of important eruptive rocks in the Rosita Hills.

Game Ridge trachyte.

The feldspathic portion of the groundmass consists of short rather stout prisms packed together, often in parallel arrangement (fig. 5)

* 'Geology of Silver Cliff and Rosita Hills, Colorado.' Whitman Cross. 17th Annual Report U. S. G. S., 1895-6, p. 306.

Orthoclase.

with a little all otriomorphicfeldspar. A few striated grains appear, which, as they extinguish parallel to or at very low angles with the twinning lines, are probably oligoclase, but fully ninety-five per cent show no striation, have a generally parallel extinction and are doubtless orthoclase.

Cross parting.

A cross parting is often noticed in the smaller phenocrysts which at first was thought to be a fracture due to pressure exerted upon the rock subsequently to its crystallization. But, although other evidences of dynamic metamorphism are seen, no displacement of the parts of these crystals could be discerned. For instance, in figure 6, the five parts into which the largest orthoclase crystal appears to be divided, extinguish simultaneously.

Bisilicates.

The hornblende is chiefly green in colour, though a few of the larger individuals are brown, resembling the hornblende of the essexite, while the green is like that of the nordmarkite. Both are trichroic having the same scheme of absorption, viz: $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$, and extinction angles, , as high as 26°—27° have been observed in each. Augite, when present is colourless, and in one instance was seen to have a fibrous rim of hornblende. Both these bisilicates are almost wholly replaced in one part of the rock by aegerine-augite (No. 187, fig. 6, plate VI), and in the same portion both a colourless and a blue sodalite mineral are quite prominent accessorics. The former is distinguished by its rounded or polygonal outlines, its isotropic character, and frequent dust-like inclusions. The latter occurs in strings and small interstitial patches, and is bright blue in ordinary and wholly dark in polarized light. Biotite occurs in comparatively few, but large, well formed individuals. Both basal and prismatic sections are seen, but present no features which call for especial notice.

Accessory minerals

Sphene is a rather abundant accessory mineral in some portions. Needles of apatite are also frequently found. A little undetermined matter occurring interstitially amongst the feldspar was thought to be altered nepheline, but may be kaolinized orthoclase.

Fourche Mountain.

The structure and mineral composition of the rock ally it with the Pulaskite type of hornblende syenite, the original occurrence of which was described by the late Dr. J. F. Williams, from Fourche Mountain, Arkansas. Its chemical relation to that rock is well shown in the following analyses, as well its resemblance to the allied mica-free sub-class, umptekite.

[illegible]	I	II	III	IV
SiO_2	59·96	60.03	59·01	58·70
TiO_2	·66		·81	trace.
Al_2O_3	19·12	20·76	18·18	19·26
Fe_2O_3	1·85	4·01	1·63	3·37
FeO	1·73	·75	3·65	·58
MnO	·49	trace.	·03	·10
CaO	2·24	2·62	2·40	1·41
BaO	·12	—	—	—
MgO	·65	·80	1·05	·76
K_2O	4·91	5·48	5·34	4·53
Na_2O	6·98	5·96	7·03	8·55
P_2O_5	·14	·07	—	·10
CO_2	none.	—	—	—
SO_3	·08	—	—	—
Cl	·14	—	·12	—
H_2O	1 10	·59	·50	2·64
	99.91	101·07	99·98	100 00

I. Pulaskite. Shefford. Analysis by M. F. Connor.
II. " Fourche Mt., Arkansas. Anal. by Brackett and Smith.
III. Umptekite, Red Hill, Moultenborough, N. H. Cited by Rosenbusch, loc. cit.
IV. Tinguaite var. Sölvsbergite, Crazy Mountains, Montana. Described by Wolff and Tarr. Bull. Mus. Comp. Zoölogy, 1893, under the name "acmite trachyte" and later renamed by Dr. Wolff as above in accordance with Brögger's classification.

In the aegerine-augite-bearing portion of this mass, the texture appears rather finer and the structure is that characteristic of trachyte (fig 6, plate VI). It then closely approaches the Sölvsberg type in appearance, and, as is shown by analysis IV, does not differ radically from it in chemical composition. Mineralogically, however, it differs from the Crazy mountain type in the character of the bisilicate constituents, which are chiefly aegerine-augite at Shefford, instead of acmite and augite intergrown with aegerine. Crazy mountain.

Nodules.

The lighter coloured of the two classes of nodules that have been mentioned consist almost entirely of orthoclase feldspar, or possibly kryptoperthite, and are somewhat similar to parts of the nordmarkite. The other is composed essentially of brown hornblende with a small amount of feldspar. The hornblende is occasionally intergrown with biotite to a small extent. Nodules of this class decompose more readily than the inclosing rock, thus forming small cavities or pits in the surface, sometimes two inches in depth. No order could be dis- Complementary nodules.

cerned in the distribution of either class. They are frequently, but not always, rounded or ellipsoidal in form, and in the latter case have the longer axes parallel to the plane of the foliation of the rock. They show no evidences of radial or concentric structure as in nodules of concretionary or spherulitic origin. Their mineralogical composition shows them to be, generally speaking, complementary parts of the pulaskite magma.

In one class of nodules the only essential mineral is feldspar similar in character to the phenocrysts of the main rock, while in the other the feldspathic constituents are of minor importance to hornblende and biotite, the former of which preponderates.

Primary origin.

They appear to be best accounted for by the segregation of their component minerals during the cooling of the general magma, perhaps analogous on a small scale to the common differentiation of an alkaline magma when it produces both bostonite and comptonite dykes from the same mass.

Comparison of Igneous Rocks.

Igneous rocks compared.

In order to give a comparative view of these rocks, their mineral constituents and chemical composition are repeated in tabular form :—

Mineralogical Composition.

—	Essexite.	Nordmarkite.	Pulaskite.
Essential constituents.	Plagioclase. Orthoclase. Hornblende (brown). Augite. Biotite.	Microperthite. Augite. Hornblende (green). Biotite (variable).	Orthoclase. Plagioclase. Hornblende (green and brown). Augite (sometimes ægerine-augite). Biotite (variable).
Accessory constituents.	Apatite. Magnetite. Sphene. Leucoxene. Sodalite. Nepheline. Quartz (rare ! !).	Magnetite. Sphene. Plagioclase. Apatite. Nepheline (rare). Sodalite (rare). Quartz.	Magnetite. Sphene. Apatite. Sodalite. Nepheline.
Structure.	Hypidiomorphic.	Hypidiomorphic.	Porphyritic trachytic.

CHEMICAL COMPOSITION.

—	Essexite.	Nordmarkite.	Pulaskite.
SiO_2	53·15	65·43	59·96
TiO_2	1·52	·16	·66
Al_2O_3	17·64	16·96	19·12
Fe_2O_3	3·10	1·55	1·85
FeO	4·65	1·53	1·73
MnO	·46	·40	·49
CaO	5·66	1·36	2·24
BaO	·13	none.	·12
MgO	2·94	·22	·65
K_2O	3·10	5·36	4·91
Na_2O	5·00	5·95	6·98
P_2O_5	·65	·02	·14
CO_2	·39	none.	none.
SO_3	·28	·06	·08
Cl	·07	·04	·14
H_2O	1·10	·82	1·10
	99·84	99·86	100·17

While the field relations of these rocks are such as to leave no doubt that they are products of three distinct intrusions, their mineralogical and chemical characters as clearly show them to be genetically related.

The most basic rock was intruded first, and that highest in silica second, while the third in order of age is intermediate in composition. All are comparatively rich in alkalies, and the greatest variation in the proportion of the bases is in lime and magnesia. The extreme range of silica is 12·28 %, alumina, 2·16 %, lime 4·30 %, magnesia 2·72 %, potash 2·26 %, and soda 1·98 %. Chemical composition.

The mean between the composition of essexite and nordmarkite, in equal proportions, approximates quite closely to the composition of pulaskite, thus:

—	Mean of Essexite and Nordmarkite.	Pulaskite.
SiO_2	59·29	59·96
TiO_2	·84	·66
Al_2O_3	17·36	19·12
Fe_2O_3, FeO	5·41	3·58
MnO	·43	·49
CaO	3·51	2·24
MgO	1·58	·65
K_2O	4·23	4·91
Na_2O	5·47	6·98

Distribution.

The areal distribution of these rocks, which is most conveniently shown by a reference to the map, cannot, however, be taken as a basis for any quantitative calculation. Nordmarkite occupies about as large an area as both the others, but it appears in places to overlie the essexite, and thus the original surface extent of that rock as well as the abyssal volume of all must remain concealed.

LATER DYKES.

Dykes.

Besides dykes of the various classes of rocks which constitute the main mass of the mountain, there are considerable numbers of later age which are themselves of at least two different ages of intrusion. They were generally distinguished in the field as the dark-coloured and light coloured dykes, a distinction that was easily made, as dykes of intermediate, or doubtful, shades were seldom if ever seen.

Two classes.

The directions of a sufficient number were measured to ascertain that no clue to their relations could thus be obtained, but the dark dykes were found to be intersected by the light-coloured ones in several instances, while no case of the reverse relation was found. Hence the classification according to colour seemed to be a natural one, a conclusion which has been borne out by a more detailed study of their mineralogical and structural characters.

Lamprophyres.

On microscopic examination it is found that the dark coloured dykes are lamprophyres, some of which by their coarser texture, presumably due to slower cooling, become an hypabyssal form of theralite, while the light coloured series consists of trachytes, which occasionally pass into bostonite. In fact the entire light coloured series probably differs in no essential respect from the bostonites of Lake Champlain described by Prof Kemp*. But as the term was employed by Prof. Kemp to emphasize their occurrence remote from any known volcanic centre, it has been thought better to use the term trachyte as the generic one in this case where dykes occur at the seat of two intrusions of a syenitic magma. The term bostonite is accordingly restricted to those specimens in which the ferro-magnesian silicates are present in less than essential amounts. In such cases too, the trachytic structure appears to be less marked.

Trachytes.

* 'The Trap Dykes of Lake Champlain,' J. F. Kemp and V. F. Marsters, U. S. Geological Survey, Bulletin No. 107, pp. 18 and 22.

Lamprophyres.

The number of fine-grained dark dykes is large and specimens have been taken from a comparatively small number of those whose macroscopic appearance is quite uniform. Dark dykes Fine-grained.

Plagioclase feldspar appears in all with one or more of the ferromagnesian minerals. Hornblende usually predominates, but both augite and biotite are in some cases prominent essential constituents. Consequently the chief type that is clearly distinguishable is camptonite, although it is probable that a microscopic examination of all the dykes wold reveal the presence of allied mica-bearing and augitic types.

Theralite.

The dykes referred to this class (Nos. 107, 107*a*, 175 *et al*) consist of feldspar, (plagioclase), nepheline, hornblende, biotite and augite, wish accessory sphene, magnetite and apatite. The plagioclase has low extinction angles measured on the albite twinning lamellæ. I am indebted to Dr. A. E. Barlow, petrographer of the Geological Survey, for the following gravity separations of the feldspars, as well as for certain other assistance with the dykes of this class. Coarse-grained.

The first feldspar that appears in the separation is in composite grains with a heavier constituent, which fell in large quantity when the density of the Thoulet solution was 2·714. On this being reduced to 2·699 a large number of composite grains fell and also a much smaller number of clear feldspar, presumably labradorite. After a further reduction of the solution to 2·651, the proportion of clear grains that appear is greater. Hence audesine is the chief feldspar present, as at 2·62 very little material fell, and that chiefly in composite or turbid grains. Feldspars.

The *Hornblende* is frequently light brown with a darker, or greenish rim, but both portions in such cases extinguish simultaneously. It is trichroic, the scheme of absorption being $\mathfrak{c} > \mathfrak{b} > \mathfrak{a}$. The maximum value observed for $c \wedge \mathfrak{c}$ was 13°. Hornblende.

The *Nepheline* has crystallized rather later than the feldspar and is thus the last mineral constituent to form; consequently its outlines are almost wholly allotriomorphic. Much of it is decomposed, the alteration product of which Dr. Barlow has determined to be 'an aggregate consisting of a radiating zeolite which possesses the optical properties of natrolite, in association with which there is also a con- Nepheline.

siderable quantity of colourless brilliantly polarizing muscovite. The nepheline also weathers to a dull colourless mineral dimly polarizing substance which is probably kaolin.'

In amount nepheline is nearly equal to feldspar. The other minerals present no features worthy of note. The structure of the rock is hypidiomorphic with a noticeable tendency towards ideomorphism on the part of the larger and probably more basic feldspars.

Camptonite.

Camptonite.

This rock is characterized in the thin section by an abundance of hornblende, always in distinct idiomorphic crystals varying in the length of prismatic sections from 2. mm. to .2 mm. In fresh crystals the colour is deep brown, with the usual pleochroism, but the greater part of the hornblende is somewhat altered, and grayish brown in colour, showing little if any pleochroism. It is studded with minute rounded or irregular grains of magnetite.

Idiomorphic hornblende.

Feldspar.

Feldspar, generally of a rather indistinct character, being somewhat turbid, is present in amount about equal to the hornblende. Lath-shaped individuals are, however, of quite frequent occurrence, and have an extinction angle of as much as 20° with the principal axis. Polysynthetic twinning is distinctly seen in a few cases. A little biotite and apatite are the remaining primary constituents. Secondary calcite occurs interstitally in considerable amount.

Undisturbed occurrence.

An isolated occurrence of this rock was found, the position of which is indicated on the accompanying map as '151.' It is there exposed in the bed of a small stream for about one hundred feet or more, at a distance of some five hundred yards from the igneous part of the mountain. It is inclosed by mica schist, and seems likely to be a sheet rather than a dyke. It appears to differ from the other rocks of the mountain in showing no deformation, but the area exposed is too small to furnish very reliable evidence of the difference in age which its unaltered character seems to suggest.

TRACHYTES.

Light-coloured dykes.

The dyke rocks that have the general characters of trachyte are uniformly fine in texture and of a light-gray, or buff, colour. When of the latter shade they pass into the bostonite type.

In thin section, feldspar is always largely in excess of the other constituents, and in some instances constitutes ninety to ninety-five per cent. of the entire rock (113, 148, 205). These are the bostonites. In an average specimen (No. 103) feldspar occupies about three-fourths of the field and occurs in small columnar crystals of uniform size and parallel arrangement, and a few larger individuals which are scarcely distinct enough to be called phenocrysts. They conform to the parallel arrangement of the lath-shaped microlites, which gives to the rock a decided flow structure. Bostonites.

Slender prismatic sections of hornblende and a little biotite can be recognized in ordinary light, as well as a few grains of magnetite, and a considerable amount of granular ferro-magnesian material. The hornblende is brown, and in a few instances shows pleochroism.

Some of the largest feldspars show very clearly a cross parting similar to that already noticed in the phenocrysts of pulaskite.

In those specimens in which the dark minerals are unimportant, or altogether wanting, the trachytic is less plainly shown. A dyke at the head of Plamondon's wood 'slide,' (No. 113) while it still shows a tendency towards parallelism of the feldspar, microlites, agrees in all essential respects with the typical bostonite of Marblhead Neck, Massachusetts. Another (No. 205) from the vicinity of the outlet of Couplands lake, also agrees very closely with this in the hand specimen, but under the microscope it shows a somewhat coarser texture.

A quartz-free porphyry from Range III Lot 24, of the Township of Shefford, a distance of about four miles from Shefford mountain, which was fully discribed by Dr. F. D. Adams (Report of Progress, Geological Survey of Canada, 1880-1-2, pp. 10-11 A) undoubtedly belongs to the intrusive masses of Shefford and Brome mountains. It probably agrees more closely with the dykes which are sent out from the nordmarkite mass, than with any of later age. Like certain nordmarkite dykes (No. 188, 135, 131) it is free from bisilicates and contains a little quartz. It differs from them chiefly in its porphyritic structure, which, however, is a feature largely dependent on the conditions of cooling. Quartz-free porphyry.

Dr. Adams thus interestingly describes it :

"This rock occurs associated with chloritic schists, and is so far as can be ascertained, conformable to these in strike and dip. In a section it is seen to be composed of a microcrystalline groundmass, Described by Dr. Adams.

holding numerous large crystals of feldspar scattered through it. These feldspar crystals have, under the microscope, a turbid appearance; they sometimes occur in simple forms, sometimes in twins according to the Carlsbad law; and one or two of them in the section showed an extinction parallel to a crystallographic axis, thereby proving that the feldspar is really orthoclase. A few plagioclase crystals, like those of orthoclase much decomposed, but showing polysynthetic twins with very narrow lamellae, are also present in the section. No quartz crystals are present in any of the three sections of this rock which have been prepared, and it has accordingly been classed as a quartz-free porphyry, although some quartz recognizable by its unaxial and positive character is present in the groundmass, so that, strictly speaking, it would probably occupy a position intermediate between the quartz and quartz-free porphyries, such rocks being by no means rare*. The rock is, however, a good deal decomposed, calcite being present in the groundmass, so that the quartz may be a secondary product.

Disseminated through the groundmass, and in smaller amount in the imbedded crystals, there are numerous opaque black grains generally irregular in shape, but sometimes occurring in little cubes. These are probably an iron ore.

Associated with these grains, at a few places in the groundmass, there is a strongly pleochroic mineral, the colours changing from light yellowish-brown to a dark-brown, and with the greatest absorption parallel to a very good cleavage. Betwee crossed nicols, extinction takes place when the plane of polarization of either prism coincides with this cleavage, so that the mineral is probably a magnesia mica. In a section, the groundmass appears of a light-brownish tint, the colour being due to a yellowish-brown mineral which is finely disseminated through it and which also accurs, though in much smaller quantity in the imbedded crystals, either in little patches or running with their cleavage lines."

Condition of Cooling of Dykes.

Dykes cooled slowly.

The prevailingly coarse texture of the dykes of Shefford mountain and the absence of glassy material in them point to their having cooled slowly, presumably due to their solidification at greater depth or to a heated condition of the side walls at the time of the injection

* Compare Rosenbusch, Mikroskopisch Physiographie der Massigen Gesteine, p. 129, ed. 1877.

of the dyke material. In the case of several dykes of nordmarkite (131, 135 et al.), which cut essexite, narrow off-shoots, scarcely a quarter of an inch in width, strike off for a distance of twenty to twenty five feet, but are scarcely less coarse in structure than the dykes themselves, which are from three to five feet wide. In neither the dykes nor their off-shoots is there any approach to a porphyritic structure.

The same character of crystalization appears in the later dykes as a rule, the chief exception being in the case of dykes probably belonging to the pulaskite mass. These, like the contact facies of that rock, have either a porphyritic or, more commonly, a porphyritic trachytic structure.

Dynamic Metamorphism.

All the igneous rocks composing the mass of Shefford mountain, with one possible exception, display more or less distinct foliation in a direction parallel to the folding of the sedimentary rocks of the district. Foliation is frequently best developed in bands a few yards in width, while the much wider intervening areas are much less altered. In the foliated bands an almost perfect or slaty cleavage is developed, and in much of the less altered portions of the rock there is a slight 'rift' or tendency to cleave, always in the same direction. Regional metamorphism.

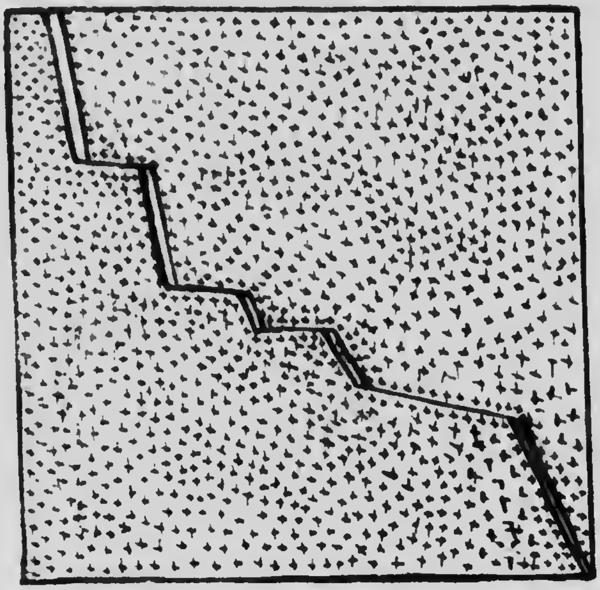
In thin sections from the least altered parts of the rock-feldspar crystals are occasionally found which are distorted and which show distinct strain shadows, thus attesting to the subjection of the rock to metamorphic agencies, at least in the final stages of the Appalachian folding.

The dykes also show evidence of subjection to pressure since their solidification. A slaty cleavage is more or less perfectly developed in both classes of dykes. That this is due to pressure is shown by the microscopic sections in which distorted crystals and grains having a wavy extinction occasionally appear. The cleavage is best shown in dykes which run obliquely to the axis of foliation. In such cases an apparent differential movement of the side walls has produced a peculiar twisted fracture crossing the dyke obliquely that is easily noticed, plate II. Cleavage.

Faulting too is well seen in numerous narrow vein-like dykes which appear in the essexite in Lavignes brook along the mountain road. Faulting.

In mineral composition and microstructure they agree completely with the bostonite dykes that have been described.

The faulting of one, about an inch and a half wide is here figured approximately to scale, the width of the vein being somewhat exaggerated.



4 feet.

Intrusions.

Owing to the intrusion of the various large masses at different periods each rock is liable to have suffered more or less deformation from the forces which caused or accompanied each subsequent intrusion. But since the latest of these possesses a cleavage scarcely less distinct than the earliest, it too must have been in its present position before the causes of the regional foliation ceased.

There is thus ample proof that the rocks of Shefford mountain have shared in the foliation of the entire region, viz., that of the Notre Dame, or Green Mountain, range of the Appalachian system. The only possible exception is the camptonite already mentioned.

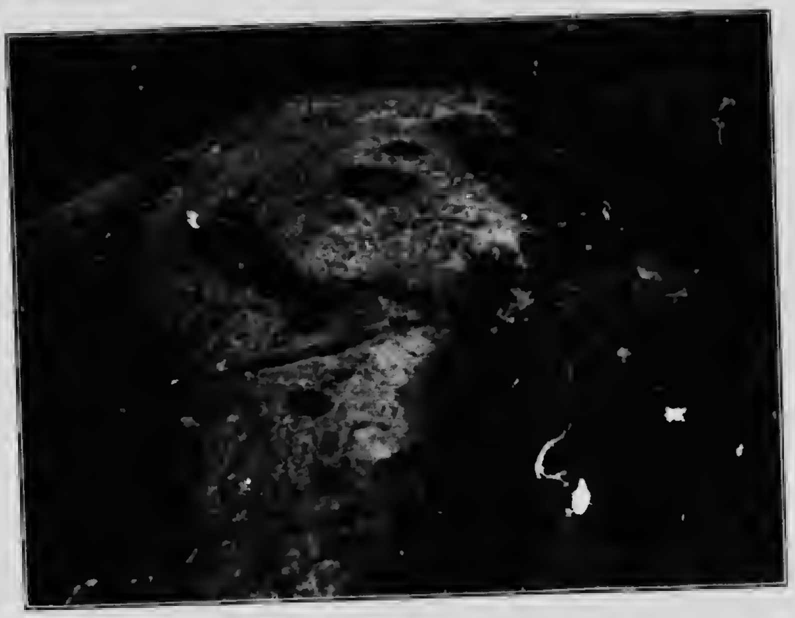
Age of Intrusive Rocks.

Important data is thus afforded for determining the age of intrusion of these rocks.

The latest sediments amongst which they have been intruded is that group of the lower Trenton formation known as the Farnham Black Slates (D 3a, map to accompany Part J, Annual Report, Geological Survey of Canada, 1894), while the earliest members of the Palæozoic system in eastern North America that have not been disturbed by the Appalachian uplift are the Permo-carboniferous of Prince Edward Island and the adjoining mainland. Accordingly, were it established that the final folding throughout all parts of the northern Appalachians took place simultaneously, the intrusion of the Shefford mass would necessarily have occurred between early Trenton and later Carboniferous time. But the simultaneous folding of so great a belt as the Appalachian system here comprises cannot be safely assumed without a better correlation of its complex structural details than is at present possible, and in consequence the latest date at which the intrusions of Shefford mountain could have taken place must meanwhile remain somewhat less precisely defined. Age of Shefford mountain.

BASIC SEGREGATION, ESSEXITE.

DYKE SHOWING CLEAVAGE.



Rusty spot in slates near contact.

Essexite, contact facies.

Fig. 1.
ESSEXITE, POLARIZED LIGHT × 45.

Fig. 2.
ESSEXITE, CONTACT FACIES, POLARIZED LIGHT × 30.

Fig. 3.
Essexite, pegmatitic facies, polarized light × 30.

Fig. 4.
Nordmarkite, polarized light × 100.

Fig. 5.
Pulaskite, polarized light × 30.

Fig. 6.
Pulaskite, Solvsbergite type, polarized light × 45.