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INTRODUCTION.

Under the name "granite" the eruptive body at Cuttingsville, on the west slope of the Green Mountains and 10 miles southeast of Rutland, Vermont, was noted in E. Hitchcock's geological report on Vermont (map and vol. 2, p. 742, 1861). In 1892 and 1894 Mr. C. L. Whittle, with an assistant, studied the Cuttingsville area for the U. S. Geological Survey, but the results of this work have not been published. In the years 1906 to 1909 the

* Shaler Memorial Investigation No. 9. The cost of publication of this paper has been defrayed by the Shaler Memorial Fund, Harvard University.

FIG. 1.

writer carried on intermittent, detailed work in the area. A summary of results was given before the Geological Society of America at Cambridge, Mass., December, 1909. An abstract was printed in the Proceedings of that meeting (vol. 21, p. 785, 1910).

In connection with the present paper, acknowledgments are due to Dr. Charles Palache, who first called the writer's attention to the Cuttingsville rocks; to Professor Wolff, under whose direction this study was undertaken; to Mr. C. L. Whittle for the use of his reconnaissance map and collections; to Professor R. A. Daly, who

FIG. 2.

FIG 2. Section along line A-B in fig. 1. Natural scale, 1: 28,000.

has assisted in the preparation of the manuscript. Special thanks are due to Dr. H. E. Merwin, now of the Carnegie Geophysical Laboratory at Washington, D. C., and to Professor C. D. Test, of the Department of Chemistry of the Colorado School of Mines, who made the excellent chemical analyses accompanying this paper.

TOPOGRAPHY.

Cuttingsville lies in the valley of Mill River on the Rutland railroad, about 1,000 feet above sea (fig. 1). The main eruptive body, 1.7 square miles (4 sq. km.) in area, is largely confined to Granite Hill (2,007 feet, fig. 3), so named from its quarries of syenite, popularly called

FIG. 1 (p. 378). Geological map of Cuttingsville district. Scale, 1: 28,000. Standard orientation.

Stock rocks—1, Essexite; 2, hornblende-biotite syenite; 3, pulaskite; 4, sodalite-nephelite syenite; 5, nordmarkite.

Dike rocks—Dotted line, essexite porphyry. Heavy broken line, syenite porphyry. Heavy full line, tinguaite. Double line, camptonite.

Country rocks—except limestone (L), not distinguished.

A-B, line of section. D, dike of type tinguaite. M, open cut for molybdenite. P, pit. Q, quarry. T, tunnel.

“granite.” This hill is crescentic in form, with a knob towards either end of the crescent, the south knob rising about 250 feet higher than the north knob (fig. 4). The shape of the hill is very suggestive of a low glacial cirque tributary to the glaciated valley of Mill Creek.

Two smaller eruptive bodies lie on the northeast side of Mill River (fig. 1), and, still farther north, a mass of breccia occupies the eastern half of a 1,400-foot hill north of Mill Creek (fig. 4). Including the breccia, the bodies extend along a line nearly $3\frac{1}{2}$ miles long. The accompanying geological maps are based upon an enlargement of adjoining parts of the Wallingford and Rutland, Vt., sheets of the topographic map of the United States.

CONDITIONS OF EXPOSURE.

Much of Granite Hill, particularly the north and east slopes of the two knobs, is thickly wooded. The bowl, crest, and west slope are fairly free from trees, but the bowl is heavily drift-covered. Along the crest, on the slopes of the north knob, and also at the east foot of each knob, where Mill Creek is actively eroding, exposures are especially numerous; those on the south knob much fewer. Three small abandoned quarries, several test pits, a prospect cut, a tunnel and a railroad cut south of Cuttingsville (see fig. 1) furnish fresh rock. Ledges and open cuts along a pyrrhotite deposit on the lower southwest slope of Copperas Hill expose a group of dikes presumably connected with the main eruptive body (fig. 5).

Excepting along the crest of the middle part of Granite Hill and for a short stretch along the crest of the south knob, contacts are rarely exposed. As mapped they are accordingly for the most part only approximate.

OUTLINE OF FIELD RELATIONS.

COUNTRY ROCKS.

The country rocks are all metamorphic—chiefly hornblende-pyroxene and mica gneisses, with considerable limestone, and quite subordinate chloritic schists and quartzite. In a zone a score or two feet wide along the only visible contact, on the west side of the main eruptive body, they show some contact metamorphism besides moderate brecciation, diking, and impregnation by eruptive rocks.

Strikes and dips of the country rocks are indicated upon the accompanying map. The strikes are commonly northeasterly, in accord with the usual Appalachian trend and run at high angles to the axis of the eruptive bodies.

Structural relations among the members of the country-rock series are obscure. The hornblendic gneisses commonly strike at an angle to the other members and are probably intrusive into them. The structural complexity makes it difficult to state the nature of the rocks beneath those actually visible. Quartzite and less certain dolomite xenoliths in the essexite of one of the northern eruptive bodies may have been derived wholly from beds formerly overlying the visible country rocks, although some may have come from beneath.

Whittle* refers the country rocks to the Algonkian and places them in a system named by him the Mount Holly, from a neighboring hill and village.

ERUPTIVE ROCKS.

The eruptive rocks include essexite, hornblende-biotite syenite, pulaskite, nephelite syenite, sodalite-nephelite syenite, nordmarkite, essexite porphyry, tinguaita, camp-tonite, and an eruptive breccia. Some of the eruptives have locally suffered slight faulting and possibly very limited crushing and shearing along certain contacts, as a result of successive intrusions and later movements; but all these rocks are entirely free from anything at all comparable to the effects of regional metamorphism displayed by the country rocks.

Composite stock.—Cross-cutting relations to the country rocks, combined with high outward dips of the contact where observable, nearly vertical flow lines, and small areal extent of the intrusive mass, indicate that the main body is a stock. In any case a laccolithic origin cannot be assumed. The composite character of the body is revealed by the distribution and structural relations of its rocks. The chief types are arranged in a roughly concentric manner (see fig. 1), essexite being partly surmounted by pulaskite and both being probably cut by the nordmarkite body.

* C. L. Whittle, The Occurrence of Algonkian Rocks in Vermont and the Evidence for their Subdivision, *Jour. Geology*, vol. 2, p. 396, 1894.

Essexite composes nearly one-quarter of the total area of the eruptives. In practically all of its occurrences it is cut by syenite or syenite porphyry, the smaller masses apparently being completely inclosed. Evidently the *essexite* represents an older body, probably a stock, which has been invaded and largely engulfed by the later intrusions. Nearly vertical contacts and occasional nearly vertical flow lines, in the *essexite* and some of the syenite, suggest that the whole forms a composite stock.

FIG. 3.

FIG. 3. Granite Hill, looking southwest.

The *pulaskite*, especially well shown on the north slopes of the bowl, constitutes about two-thirds of the main eruptive body. It clearly penetrates the *essexite* and gneisses. In places it extends west of the crest of the middle part of Granite Hill (fig. 3), forming, where *essexite* is present, a band of no great width between the *essexite* and gneisses.

Between flanking lenses of *essexite* and occupying the crest of the middle part of Granite Hill, is an area of *hornblende-biotite syenite*, upwards of 1,000 feet long and half as wide. It appears again, in a much narrower band, near the crest of the north knob. Its total areal extent is believed to be least of all the chief types of rock exposed on Granite Hill. Its structural relations to both the *essexite* and the *pulaskite* are somewhat obscure, due to the failure of sharp contacts. A point bearing upon this question, however, is the very common development of a biotite-hornblende phase of the *pulaskite* on the side towards the *essexite*. These border phases frequently

resemble very closely the type hornblende-biotite syenite in the quarry near the crest of the middle part of Granite Hill.

These facts might be explained on the assumption that the hornblende-biotite syenite is a sort of hybrid, having resulted from the assimilation of essexite by pulaskite. This view accords with the usual absence of sharp contacts between pulaskite and essexite, the one gradually passing into the other, as illustrated in a narrow band near the crest of the north knob.

However, in the quarry the hornblende-biotite syenite itself is cut by an apophysis or irregular dike of syenite porphyry merging into porphyritic syenite. If it is a tongue from the main mass of pulaskite, the view that the hornblende-syenite is a hybrid of essexite and pulaskite must be relinquished in favor of early differentiation and intrusion coincidently with or immediately succeeding the essexite, but preceding the pulaskite.

The *nordmarkite* is clearly intrusive into the essexite, cutting it freely and inclosing fragments, as well shown in the contact zone of essexite and nordmarkite on the north knob. Its relations to the other syenites are obscure. On the lower southeast slope of the north knob, the path to the quarry has been cut in bedrock which shows quartz-syenite dikes penetrating a pulaskitic type.

A similar combination, with gneiss fragments also included, is shown in excavated blocks at the edge of Mill River just below. This is the only recorded evidence that nordmarkite intrudes eruptives other than essexite, and it is not conclusive. The nordmarkite along Mill River, at the east foot of the north knob of Granite Hill, is cut by several large dikes of syenite porphyry.

These may possibly be apophyses from the pulaskite, though there are certain field, lithological, and chemical reasons for believing these syenite-porphyry dikes to be intrusions later than both nordmarkite and pulaskite, and connected with the nephelite syenite.

The *sodalite-nephelite syenite* in the railroad cut is probably considerably less extensive than any type on Granite Hill. Very similar rock exposed on the lower east slope of the south knob, in a small detached outcrop, on the west shore of Mill River, may indicate that the area extends into Granite Hill. The structural relations are completely hidden. The rock is either a sodalite-

bearing phase of the pulaskite and contemporaneous with it, or, as just suggested, a distinctly later intrusion.

Smaller igneous-rock areas.—The two smaller areas north of Granite Hill appear to be parts of one irregular, composite intrusion, fed from the same magma reservoir as the main body. It is quite possible that the northern areas are continuous with the Granite Hill mass, beneath the cover of drift and alluvium in Mill River Valley. If so, this would increase the length of the area of the Granite Hill stock by about three-quarters of a mile, and give it a pronounced northward elongation.

The northern eruptives, where exposed, are much more involved with the country rocks than is the case on Granite Hill. Contorted and brecciated gneisses frequently alternate with eruptives along the railroad, and flank them on the northwest. The geological map, owing to the limitations of its scale, gives a quite inadequate impression of the intricate relations between eruptives and country rock, especially in the case of the more northern area.

The rocks of the northern areas resemble those on Granite Hill, but nordmarkite and the more basic phases of essexite are absent. Thick dikes of camptonite with numerous inclusions are the more impressive features in the northern areas.

Although not so well shown as on Granite Hill, the syenite of the northern areas is nevertheless clearly intrusive into the essexite, probably vertically, judging from limited contacts and nearly vertical flow lines in some of the syenite. The essexite carries occasional xenoliths of quartzite, hornblende gneiss, and possibly of dolomite, and is probably a quite irregular intrusion. The syenite, although not chemically or microscopically studied, is regarded as partly pulaskite and partly biotite syenite (with some hornblende). The latter has been mapped under the same symbol (2, fig. 1) as the hornblende-biotite syenite of Granite Hill, which rock it most resembles.

Breccia mass.—About three quarters of a mile north of the small areas of eruptive rock just described, there is a body of breccia, shown in fig. 4. Though not closely studied it appears to represent shattering by faults. The constituent fragments, never more than a few centimeters in diameter, are composed of quartzite, with subordinate schist and gneiss. In its southern part the

breccia is intimately injected by a trappean rock, possibly an essexite porphyry. The exposures indicate an elongate mass, about half a mile long and 500 feet wide, lying *en axe* with the eruptive bodies. The eruptive rocks of the small areas farther south are bordered by, and alternate with, brecciated country rock. All the breccias may form a single band, the most northerly mass being not so much injected by igneous rock because of greater distance from the eruptive center.

FIG. 4.

FIG. 4. Area of breccia, two miles northwest of Cuttingsville. Standard orientation. Scale, 1:21,000. Area shown is nearly continuous with that of figure 1. B, breccia. L, limestone. Other rocks not distinguished.

Dikes.—Associated with the plutonic rocks are numerous dikes, both aschistic and diaschistic. They comprise, in the inferred order of intrusion, essexite porphyry, nephelite syenite, syenite porphyry, aplite tinguaitite, and camptonite.

As a whole the dikes have not been thoroughly diagnosed. Two, a syenite-porphyry dike and a tinguaitite dike, mapped respectively at *T* and *D*, fig. 1, have been chemically studied. Classification of the other dikes is tentative. Some mapped as tinguaitite may, upon further study, prove to be fine-textured phases of syenite porphyry, or possibly bostonite. Others mapped as

camptonite may prove to be fine-textured essexite porphyries.

The dikes range in thickness from a fraction of an inch to 25 feet, with an average of about one foot. The dikes are most numerous in or near eruptive areas. They rarely occur more than half a mile distant. In the eruptive areas they are not confined to any particular kind of plutonic rock, though they seem to be more numerous near contacts of the syenites with essexite.

DATE OF ERUPTIVITY.

There is little direct evidence bearing upon the exact geological age of the eruptives. They are clearly of later date than the gneisses and limestone of supposed Algonkian age. Their freedom from marked crushing and shearing suggests that the intrusions did not consolidate until after the strong deformation of the country rocks had been accomplished. Assuming that the last of these could not have been earlier than late Carboniferous times, when the whole Appalachian province was greatly disturbed, it may be inferred that the Cuttingsville eruptives do not antedate the close of the Carboniferous period. Similar intrusions, at Ascutney Mountain, not more than 25 miles distant, are regarded as probably of post-Carboniferous and pre-Cretaceous age.¹

PETROGRAPHY.

COUNTRY ROCKS.

Gneisses.—The gneisses are of two kinds, a basic hornblende-pyroxene gneiss and a mica gneiss which is more or less granitic. The former is the more abundant in the immediate neighborhood of the eruptives, and more study has been devoted to it on that account. It is typically a heavy, rather dense, fine- to medium-grained, black rock, weathering a streaked or speckled brownish gray. The thin section shows about equal amounts of olive-brown to green hornblende and pale greenish pyroxene. In addition there is subordinate brown biotite and plagioclase with some orthoclase and doubtful quartz. Magnetite and apatite are accessory. The rock is

¹ R. A. Daly, U. S. Geol. Surv., Bull. 209, p. 21, 1903.

inferred to be a metamorphosed eruptive of gabbroid, diabasic, or basaltic character.

Limestone.—The limestone (L, figs. 1 and 4) varies considerably in texture, mineral content, and degree of metamorphism. It is quite subordinate to the gneisses as a member of the country rock series. It crops out at four localities about the main eruptive body and also about one-half mile west of the area of breccia shown in fig. 4.

The limestone on the southwest slope of Granite Hill and on Mill River varies in color from bluish gray through cream to white. It is fine-grained although the sparkle of the calcite cleavage is distinctly visible. It effervesces freely with dilute hydrochloric acid. Under a hand lens grains of quartz and particles which are probably graphite are noticeable.

On the southwest slope of Copperas Hill (fig. 1) one or more bands of crystalline limestone follow the easterly to northeasterly strike and high dips of the enclosing gneisses. One of the bands has an exposed width of 20 feet. In working the pyrrhotite bodies which replace the limestone along the belt of tinguaitite dikes on this slope of Copperas Hill (fig. 1) cuts have been made in masses of limestone 5 to 15 feet thick associated with hornblende gneiss. This limestone is light bluish gray to white in color, fairly coarse-grained, and distinctly metamorphic. The metamorphism is presumably due to regional rather than igneous contact action. Hand specimens show, besides calcite, generally considerable muscovite or sericite, and more locally, abundant flakes of graphite. Some bands carry much tremolite or wollastonite developed in short prisms and fibers along the planes of schistosity. All samples effervesce freely with dilute hydrochloric acid.

One half-mile southeast of the Granite Hill eruptive a bed of coarsely crystalline tremolitic limestone about 15 feet thick is associated with quartzite and hornblende and mica gneisses, and is cut by a dike of camptonite or essexite-porphry.

The limestone indicated in fig. 4 varies from light gray and medium-grained, with occasional graphite flakes, to cream white and decidedly coarse-grained, with quartz veins and considerable muscovite. There is a notable amount of limestone altogether, although it soon passes into sericitic schist.

Quartzite.—Micaceous quartzite forms a few thin beds or lenses in gneiss and limestone. Granular quartzite is relatively abundant as fragments in the breccia, and as xenoliths in the essexite of the northern eruptive area.

Schists.—Sericitic, chloritic, and tremolitic schists occur only as thin bands between much thicker beds of quartzose gneiss, hornblende gneiss, and crystalline limestone.

STOCK ROCKS.

The rocks of the stocks will be described in the order from oldest to youngest, which is also the order from basic to acid (1, figs. 1 and 2).—Fresh essexite is exposed in cuts on both sides of the crest of the central part of Granite Hill and along the path to the quarry, near the top of the hill. It varies from a nearly black, fairly uniform, medium- or coarse-grained gabbroid rock, to a gray, more or less porphyritic phase.

The *type phase* was taken for study from an open cut or pit (P, fig. 1) on the southwest side of the crest of the middle part of Granite Hill, less than 1,000 feet south of the hornblende-biotite syenite quarry (Q 2, fig. 1). The same phase has been freshly cut on the other side of the crest along the path near the quarry, and rock much like it is exposed by Mill River at the east foot of the south knob. It is dark-colored, sometimes almost black, and usually coarse-grained. Barkevikitic hornblende, showing luster-mottling, is generally prominent in the hand specimen.

Thin sections show coarse-grain and hypidiomorphic-granular texture. About 60 per cent of the rock is feldspar, mostly plagioclase, ranging from $Ab_7 An_3$ to $Ab_3 An_7$. From 5 to 10 per cent of the rock is orthoclase, which appears in small- and medium-sized grains and irregular areas sometimes intergrown with, enclosing, or embaying the plagioclase. The other essentials are hornblende, pyroxene, and biotite, in nearly equal amounts.

Of the dark-colored minerals barkevikitic hornblende is most notable. Its optical properties are sensibly identical with those of the hornblende in the hornblende-biotite syenite, and will be stated at length in the description of that rock. The pleochroism of the hornblende of the essexite shows, however, more reddish or chestnut tints

in the darker colors. Poikilitic inclusions of pyroxene and, in less amount, biotite and olivine give rise to the luster-mottling visible in the hand specimen.

Pyroxene is represented by augite of two colors, pale green and pale brown. The colors appear separately or sometimes together in the same grain. A pale brown center may be bordered by pale green, with a zone of inclusions of magnetite and hornblende between the two colors. The differently colored parts are optically continuous and extinguish together. When occurring separately, a maximum extinction angle of 44° for the green and 37° for the brown was observed. The augite and hornblende are remarkably intergrown, the latter surrounding augite which in turn incloses grains of hornblende.

Biotite is in thick tables, besides forming striking intergrowths with hornblende. Its pleochroism ranges from pale yellow to chestnut and deep brown or nearly black.

Olivine in occasional large grains, partly serpentinized, enters the list of accessory minerals, which also includes magnetite, titanite, apatite, pyrite, and probably pyrrhotite.

One of the sections includes an irregular area of what is possibly cancrinite derived from original nephelite. This is the only suggestion of the presence of nephelite, indicating that it is seldom, if at all, a constituent.

Texture and mineralogical composition place the rock among the alkali-gabbros under the head of essexite. Chemical analysis supports this conclusion.

	I	II	III	IV	V	VI	VII
SiO ₂	46.47	46.99	48.85	44.00	49.96	47.90	48.64
TiO ₂	2.86	2.92	2.47	1.90	2.40	1.91	1.86
Al ₂ O ₃	16.86	17.94	19.38	27.73	18.83	16.55	17.96
Fe ₂ O ₃	3.21	2.56	4.29	2.36	2.52	5.67	4.31
FeO	7.72	7.56	4.94	3.90	6.64	7.50	5.58
MnO	0.23	Trace	0.19	0.08	0.20	0.60	0.19
MgO	5.16	3.22	2.00	2.30	3.52	4.44	4.00
CaO	9.45	7.85	7.98	13.94	7.42	9.35	8.89
Na ₂ O	4.20	6.35	5.44	2.36	5.26	3.23	4.30
K ₂ O	1.35	2.62	1.91	0.45	2.58	2.08	2.28
H ₂ O+	0.45	0.65	0.68	0.80	0.07	0.20	1.34
H ₂ O—	0.04				0.53		
P ₂ O ₅	1.15	0.94	1.23	0.20	0.25	0.32	0.65
CO ₂	Trace						
ZrO ₂	None						
SO ₃	None		not det.				
Cl	0.06						

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	I	II	III	IV	V	VI	VII
F	0.10						
Cr ₂ O ₃	None						
BaO	Trace						
SrO	0.04						
FeS ₂	0.21						
Fe ₂ S ₃	0.08						
Li ₂ O	None						
Sum	99.64	99.60	99.36	100.01	100.18	99.75	100.00
Specific gravity		2.919					

I = Essexite, type phase (andose), Cuttingsville, Vt., H. E. Merwin, analyst.

II = Essexite (essexose), Salem Neck, Essex Co., Mass.

III = Normal essexite (andose), Mt. Johnson, Quebec.

IV = Essexite (hessose), Brome Mt., Quebec.

V = Essexite (sailemose), St. Hilaire Mt., Quebec.

VI = Essexite (camptonose), Tofteholmen, Norway.

VII = Essexite (average of 20 analyses, R. A. Daly, in "Igneous Rocks and Their Origin," 1914, p. 30).

The rock is an andose, allied to camptonose, with the following norm:

Orthoclase	7.78	Olivine	9.93
Albite	27.25	Magnetite	4.64
Anorthite	23.35	Ilmenite	5.47
Nephelite	4.54	Apatite	2.48
Diopside	13.07	Water, etc	.98
			99.49

Comparison of the Cuttingsville essexite shows its close similarity to the type from Essex County, Massachusetts, and to the varieties of essexite from the Montegregian Hills, Quebec. The likeness in chemical composition to the essexite from Tofteholmen, Norway, is but one example of a striking chemical similarity between the Cuttingsville rocks and some of those of southern Norway.² The table facilitates comparison with the average essexite as computed by Daly from twenty analyses.

One of the variations from the type phase apparently results from the local impregnation and partial assimilation of essexite by pulaskite. Hand specimens usually show dikelets and streamers of this syenite, traversing essexite. The color resulting from the combination of pulaskite with essexite is lighter and the grain less uniform than in simple essexite. Idiomorphic hornblende and more or less definitely bounded feldspars are sometimes noticeable. A characteristic feature is an abundance of titanite.

² Brögger, W. C., "Die Eruptivgesteine des Kristianiagebietes": Vidensk. Skrifter I, No. 4, 1894; No. 7, 1895; No. 6, 1897.

Sections show a greater proportion of feldspars than simple essexite. About 70 per cent is feldspar, of which approximately one-third is orthoclase and two-thirds plagioclase, of a composition intermediate between basic oligoclase and andesine. There is some microperthite, and possibly altered nephelite and cancrinite. The remaining chief constituents are: hornblende, sometimes surrounded by, and intergrown with, olive-brown biotite; and augite poikilitically inclosed in hornblende.

The rock may be regarded as a more acid essexite, which with the hornblende-biotite syenite itself occurs in the series between essexite and pulaskite.

On the north knob of Granite Hill an extremely *coarse-grained phase* of essexite is developed. It is largely composed of prisms of hornblende, some upwards of 2 inches in length. A little biotite is visible in the hand specimen. The amount of feldspar varies. Towards pulaskite contacts the proportion of feldspar increases, and the rock grades into a very coarse hornblende-biotite syenite. This gradation is quite clearly shown near the crest of Granite Hill, from the north knob to the molybdenite prospect (M, fig. 1).

Porphyritic phases form important parts of the more extensive essexite areas. They are also exposed as smaller masses which appear to be apophyses and detached portions of the main bodies. The groundmass varies from coarse to almost aphanitic. The phenocrysts are usually hornblende, commonly an inch or two in length, frequently much less, and sometimes very much greater. In one case the measured dimensions of a hornblende phenocryst were 15 by 8 inches. Biotite appears, with or without hornblende, usually in the groundmass.

The porphyritic phases quite generally carry large and small inclusions, apparently of the coarse phases of essexite and hornblende-biotite syenite. These inclusions are not always so sharply defined as accompanying inclusions of the country rocks, but they seem to demonstrate an intrusion of porphyritic essexite into an earlier intrusion of more uniformly coarse-grained essexite and possibly syenite. The blurred outlines of the inclusions suggest that the interval between the earlier and the later intrusion was comparatively short.

Hornblende-biotite Syenite (2, figs. 1 and 2). Hornblende-biotite syenite is of smaller total area than most of the other plutonic types. Its principal exposures are near the crest of the central part of Granite Hill, where a small quarry was opened about 25 years ago.

The *type* phase, taken from the quarry (Q 2, fig. 1), is moderately coarse-grained, almost white in ground color, and abundantly specked with black amphibole and mica. Occasionally a slightly darker-colored, finer-grained, indistinct patch or schlier, a few centimeters in dimensions, appears in the hand specimen.

In thin section the hornblende-biotite syenite shows a hypidiomorphic, medium to coarse granular texture. Eighty per cent or more is feldspar, of which the bulk is plagioclase, in composition intermediate between basic oligoclase and andesine. About one-third of the feldspar is orthoclase, some of which is intergrown with plagioclase.

After the feldspars, amphibole is most notable. It appears in well-defined prisms, commonly twinned. The pleochroism is distinctive, green to greenish brown in the direction of the *c* axis; dark greenish brown to almost black parallel to the *b* axis; and pale yellow parallel to the *a* axis. The absorption scheme is $b > (\text{nearly} =) c > a$. The extinction angle on (110) cleavage pieces is 12° . $2E = 70^\circ - 80^\circ$ or less. A calculation of the angle of extinction on (010) gave 8° . The specific gravity, by pycnometer, at 20°C. , is 3.518. These characteristics taken together indicate a soda-amphibole near barkevikite.

In order to check the optical determination of the amphibole, a chemical analysis of the amphibole was made by Professor C. D. Test of the Department of Chemistry of the Colorado School of Mines. Good material was obtained by the usual modes of separation from the rock powder. The analysis resulted in the values given in Column I of the following table, in which those for related amphiboles are also entered:

	I	II	III	IV	V	VI
SiO ₂	38.04	38.633	40.10	42.46	42.27	38.41
TiO ₂	1.06	5.035	4.35	(In SiO ₂)	1.01	1.26
Al ₂ O ₃	13.50	11.974	10.88	11.45	6.31	16.39
Fe ₂ O ₃	6.21	3.903	7.81	6.18	6.62	3.75
FeO	15.85	11.523	9.66	19.93	21.72	21.75
MnO	1.21	0.729	0.15	0.75	1.13	0.15

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	I	II	III	IV	V	VI
MgO	7.26	10.200	9.74	1.11	3.62	2.54
CaO	12.42	12.807	12.60	10.24	9.68	10.52
Na ₂ O	3.21	3.139	3.18	6.08	3.14	2.95
K ₂ O	1.68	1.489	1.60	1.44	2.65	1.95
H ₂ O (by ignition)	0.48	0.330	0.00		0.48	0.24
F			0.31			
P ₂ O ₅			0.63			
Sum	100.92	99.762	101.01	99.64	98.63	99.96

I = Hornblende from Cuttingsville hornblende-biotite syenite, C. D. Test, analyst.

II = Hornblende from Mt. Johnson, Quebec, essexite, F. D. Adams, Jour. Geology, vol. 11, p. 260, 1903.

III = Hornblende from Heum, Norway, heumite, J. P. Iddings, "Rock Minerals," 1906, p. 338.

IV = Barkevikite from Barkevik, Norway, nephelite syenite, *ibid.*, p. 339.

V = Barkevikite from Barkevik, Norway, syenite, *ibid.*, p. 339.

VI = Barkevikitic hornblende from Square Butte, Mont., sodalite syenite, L. V. Pirsson, U. S. Geol. Surv., Bull. 237, p. 67, 1905.

Chemically, as well as optically, this Cuttingsville amphibole is seen to be a barkevikitic hornblende.

Chief among the remaining minerals, in thin sections of the type phase of the Cuttingsville hornblende-biotite syenite, is brown biotite which is present in amount nearly equal to hornblende. There are occasional triangular and irregular areas, filled with alteration products probably derived from nephelite, which is not otherwise represented in the type phase of the syenite, though visible to the naked eye in coarser-grained segregations to be described hereafter.

Apatite, titanite, magnetite, zircon, and pyrite are accessory.

The abundant plagioclase allies it to monzonite, but the ratio of dark silicates to feldspar warrants the designation of the rock as a hornblende-biotite syenite. Its analysis is given in the succeeding table (column I), which introduces relevant analyses from similar rock bodies and also the average analysis of laurvikite:

	I	II	III	IV	V	VI	VII
SiO ₂	57.44	57.44	59.96	59.01	56.85	57.12	57.45
TiO ₂	0.69	1.97	0.66	0.81			
Al ₂ O ₃	21.60	19.43	19.12	18.18	21.56	21.69	21.11
Fe ₂ O ₃	0.20	1.69	1.85	1.63	3.44	1.63	2.89
FeO	2.62	2.70	1.73	3.65	1.14	3.65	2.39
MnO	0.14	0.25	0.49	0.03			
MgO	1.09	1.16	0.65	1.05	0.85	1.55	1.06
CaO	2.90	2.66	2.24	2.40	5.26	4.03	4.10
Na ₂ O	7.36	6.48	6.98	7.03	6.07	5.93	5.89
K ₂ O	4.12	4.28	4.91	5.34	3.66	3.48	3.87

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	I	II	III	IV	V	VI	VII
H ₂ O+	0.58	1.03	1.10	0.50	0.52	0.58	0.70
H ₂ O—	0.03			0.15			
P ₂ O ₅	0.38	0.60	0.14	Trace			0.54
CO ₂	0.39						
ZrO ₂	0.02						
SO ₃	None	not det.	0.08				
Cl	0.07	Trace	0.14	0.12			
F	0.05						
Cr ₂ O ₃	None						
BaO	0.26	not det.	0.12	0.08			
SrO	0.04						
FeS ₂	0.15						
Fe ₂ S ₃	0.14						
Li ₂ O	None						
Sum	100.27	99.69	100.17	99.98	99.35	99.66	100.00

- I = Hornblende-biotite syenite, type phase (laurvikose), Cuttingsville, Vt., H. E. Merwin, analyst.
 II = Pulaskite (laurvikose), Mt. Johnson, Quebec.
 III = Pulaskite (laurvikose), Shefford Mt., Quebec.
 IV = Umptekite (umpteke), Red Hill, Moltonboro, N. H.
 V = Laurvikite (laurvikose), Notterö, Norway.
 VI = Laurvikite (laurvikose), Frederiksvärn, Norway.
 VII = Laurvikite (average of 3 analyses, R. A. Daly).

- II, III Quoted from F. D. Adams, Jour. Geology, vol. 11, p. 271, 1903.
 IV, V, VI “ “ Washington, H. S., “Chemical Analyses of
 Igneous Rocks”: U. S. Geol. Surv., Prof.
 Paper 14, pp. 253, 203, 1903.
 VII “ “ Daly, R. A., “Igneous Rocks and Their Origin,”
 p. 23.

The norm (laurvikose) was calculated to be:

Orthoclase	24.46	Ilmenite	1.36
Albite	44.01	Magnetite	0.23
Nephelite	9.94	Corundum	0.31
Anorthite	12.81	Apatite	0.93
Olivine	4.75	Water, etc.	1.47
		100.27	

A *coarse-grained phase* of this syenite is best shown in a narrow belt between essexite and pulaskite, extending for a part of the distance between the summit of the north knob and the molybdenite prospect (M, fig. 1) near the crest of Granite Hill. Hornblende in prisms, occasionally upwards of 2 inches in length, is the most prominent constituent. Flakes of biotite, sometimes half an inch across, are sparsely scattered through the rock. Titanite and pyrite are visible without a lense. As the

proportion of feldspar, much of which is plagioclase, diminishes, the rock becomes dark-colored and gabbroid, and grades into coarse-grained essexite.

A strongly *biotitic* phase of medium grain, and with a somewhat greater proportion of dark silicates than in the type phase, is exposed along the railroad in the first small eruptive area north of the Granite Hill area (fig. 1).

In the hornblende-biotite syenite of the quarry on Granite Hill (Q 2, fig. 1), *foytitic schliers* are not uncommon. Some appear to be segregations. Others are more sharply defined, elongate, and dike-like. They are usually small, but may attain a width of several inches and a length of 2 or 3 feet. The larger are coarse-grained, with gray nephelite, sometimes an inch or more in diameter, white or pearl-gray feldspars, and an occasional biotite flake or hornblende prism. Thin sections of these schliers show microperthite, some plagioclase, nephelite, colorless sodalite, hornblende, titanite, and magnetite. In the finer-grained rock there also appear olive-brown biotite, pyrite, and possibly cancrinite and zircon as subordinate accessories.

Pulaskite (3, fig. 1).—This rock is usually coarse-grained and much weathered. The *type phase* is essentially a coarse-grained aggregate of hypidiomorphic, gray-white feldspars, which weather cream-white, yellowish, or brownish. Biotite is generally present, becoming abundant in some varieties.

A thin section of comparatively fresh rock from the exposure along Mill River at the east foot of the south knob of Granite Hill shows the rock to be composed chiefly of microperthitic feldspar with a little orthoclase. One area probably represents cancrinite derived from original nephelite. A little nephelite is almost certainly present in some other hand specimens. Titanite, magnetite, pyrrhotite, apatite, and zircon are accessory; the sulphides and titanite are sometimes macroscopically visible.

Some of the weathered rock from the upper southward slope of the north knob of Granite Hill appears to carry a little augite, as well as some biotite. If so, it approaches augite syenite in composition, but is decidedly more feldspathic and coarser-grained than the typical augite syenite or nordmarkite (5, fig. 1) of the northward slope of the north knob. It has been a difficult matter to

draw a line between the two in mapping their respective areas. It is possible that there is no such line, and that the pulaskite and nordmarkite are really one body, more augitic and nordmarkitic on the north and more feldspathic and pulaskitic on the south.

Coarse-grained phases of pulaskite are very strikingly developed near the crest of the middle part of Granite Hill. It occurs as ill-defined apparently northward-trending streaks or schliers, about a foot wide, in syenite not quite so coarse. The rock is practically all feldspar, in chunks or rough crystals, some upwards of 2 inches in length.

A noteworthy point about some of the coarse-grained phases of the Cuttingsville eruptives is their proximity to eruptive contacts, suggesting that their coarseness of grain is partly due to the action of gases emanating at contacts.

Biotitic phases of the pulaskite develop near contacts with essexite. This is notably the case on the north knob of Granite Hill, and in the exposures along Mill River at the east foot of the south knob.

A peculiar coarse biotitic phase is developed in small amount between essexite and normal pulaskite in the pit (P, fig. 1) south of the quarry. Similar rock, with the same association of essexite and normal pulaskite and in limited amounts, is exposed on the path near the quarry. Penetrating the usual coarse, hypidiomorphic gray-white feldspars are skeleton flakes of biotite up to one inch in diameter. The flakes are quite numerous and lie in various attitudes. Consequently a broken surface of the rock shows a number of roughly radiating black lines, which are the traces of the wide flakes broken across. Besides these, some flakes, luster-mottled as a result of their skeletal structure, appear full face.

Fine-grained and *porphyritic phases* of pulaskite appear frequently along contacts.

The pulaskite of the two small eruptive areas (fig. 1) north of the Granite Hill area is mostly medium grained.

Sodalite-nephelite Syenite (4, fig. 1).—The sodalite-nephelite syenite at the railroad cut is a holocrystalline, moderately coarse-grained aggregate of light-gray feldspar of tabular habit, rather frequently in Carlsbad twins, with interstitial black pyroxene and brownish

nephelite. Minute grains and small masses of pyrite are disseminated through the rock. Blue sodalite is rarely discernible in the hand specimen.

Thin sections show about 90 per cent feldspar, of which upwards of one-half is microperthite, orthoclase, and microcline. Both the orthoclase and microcline are somewhat microperthitic. Some form of microperthite is thus the chief feldspar. A part is possibly anorthoclase. The plagioclase is near albite in composition. Colorless sodalite forms angular and veinlike areas between and penetrating the feldspars. The chemical analysis indicates its amount as about 3 per cent. The nephelite, with nearly equal abundance, is in various stages of alteration, to cancrinite, zeolites, and muscovite. Pyroxene is next to the feldspars in abundance. It is a pleochroic variety, the color ranging from pale yellowish green through olive-green to green. Extinction angles indicate an ægirite-augite somewhat nearer ægirite than augite. There is some biotite bordering, penetrating, and included in the ægirite-augite.

The order of crystallization is given in the following list, which shows also the nature of the accessories: (1) apatite; (2) magnetite, titanite, and possibly pyrite; (3) biotite; (4) ægirite-augite; (5) plagioclase; (6) sodalite, nephelite, and most of the feldspars.

The chemical analysis (column I of the following table) agrees with the mineralogical composition in referring the rock to the sodalite-nephelite syenites. For convenience the analyses of other types are also entered:

	I	II	III	IV	V	VI
SiO ₂	60.88	56.45	60.20	60.13	58.61	61.86
TiO ₂	0.35	0.29	0.14	1.15	1.10	0.15
Al ₂ O ₃	20.75	20.08	20.40	20.03	21.12	19.07
Fe ₂ O ₃	0.63	1.31	1.74	2.36	2.62	2.65
FeO	1.13	4.39	1.88	1.33	1.14	1.49
MnO	0.22	0.09	Trace	Trace	Trace	0.01
MgO	0.17	0.63	1.04	0.76	0.79	0.55
CaO	1.08	2.14	2.00	0.87	0.62	1.47
Na ₂ O	6.35	5.61	6.30	6.30	7.85	6.45
K ₂ O	5.57	7.13	6.07	5.97	5.93	5.75
H ₂ O +	0.88	1.51	0.23	1.41	1.01	0.47
H ₂ O —	0.03	0.26	0.10	0.16		
P ₂ O ₅	Trace	0.13	0.15	0.06	Trace	0.08
CO ₂	0.61		None	None		
ZrO ₂	Trace		Trace	0.05		
SO ₃	None		0.13	0.14		
Cl	0.18	0.43	0.09			

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	I	II	III	IV	V	VI
F	0.05					
Cr ₂ O ₃	None					
BaO	0.02					
SrO	Trace					
FeS ₂	0.61					
Fe ₂ S ₃	0.13					
Li ₂ O	None					
Sum	99.64	100.45	100.47	100.72	100.79	100.00

I = Sodalite-nephelite syenite, type phase (nordmarkose), Cuttingsville, Vt., H. E. Merwin, analyst.
 II = Sodalite syenite (pulaskose), Square Butte, Mont.
 III = Pulaskite (pulaskose), Fourche Mts., Ark.
 IV = Foyaite (phlegrose), Fourche Mts., Ark.
 V = Aegirite—kataforite foyaite (miasikose), Heum, Norway.
 VI = Pulaskite (average of 5 analyses, R. A. Daly).

II, III, IV, V Quoted from Washington, H. S., U. S. Geol. Surv., Prof. Paper 14, pp. 201, 199, 195, 211, 1903.
 VI “ “ Daly, R. A., “Igneous Rocks and Their Origin,” p. 22.

The rock is a nordmarkose, near phlegrose, with the following norm:

Orthoclase	32.80	Magnetite	.93
Albite	53.45	Ilmenite	.61
Anorthite	5.28	Corundum	2.35
Hypersthene	1.72	Water, etc.	2.51
			99.65

A comparison of columns I, III, and VI tends to support the view that the sodalite-nephelite syenite is a phase of the Cuttingsville pulaskite.

Augite Syenite (Nordmarkite) (5, fig. 1).—In the middle of the last century, during the construction of the railroad, openings were made in the north end of Granite Hill, and a considerable amount of stone quarried for bridge foundations. This stone is popularly known as green granite from its light olive-green color. The grain is usually medium, but there are fine-grained and decidedly coarse-grained phases. In total areal extent it is probably second only to the pulaskite.

The *type phase* is a medium-grained aggregate largely of hypidiomorphic feldspar. Grains of black augite and occasional small grains of quartz are usually discernible.

The rock on the fresh fracture is bluish gray to gray-green in color. This color changes in a few weeks indoors to olive or brownish green.³ The change is pre-

³ This remarkable behavior is paralleled in the case of the nordmarkite of Asectney Mountain. (See R. A. Daly, U. S. Geol. Surv. Bull. 209, p. 51, 1903.)

sumably due to the oxidization of iron sulphide or some other substance disseminated through the feldspar. The rock yields a strong sulphurous odor while being broken. Out-door weathering rusts the rock surface, finally changing the color to pale buff or very light brown.

In thin section the texture is holocrystalline, hypidiomorphic granular. Seventy-five per cent or more is feldspar, of which microperthite is most notable and is accompanied by microcline, probably anorthoclase, orthoclase, and a little albite. Green augite, locally rimmed with green hornblende, is chief of the remaining minerals. With it there is some ægirite-augite whose extinction angle approaches that of ægirite. An occasional large grain of olivine (fayalite?), more or less serpentinized, and a little primary quartz, in distinct grains, are usually present. Magnetite, possibly some ilmenite, zircon, and apatite are accessory. A single, large crystal, possibly allanite, was noted in one section.

The mineralogical composition indicates that the rock is an augite syenite of the nordmarkite group, a conclusion borne out by a comparison of its chemical analysis (column I of the following table) with other nordmarkitic types and with average nordmarkite (column VII).

	I	II	III	IV	V	VI	VII
SiO ₂	67.30	65.43	65.43	60.45	66.13	67.99	64.36
TiO ₂	0.17	0.16	0.50		0.74		0.45
Al ₂ O ₃	17.44	16.96	16.11	20.14	17.40	17.54	16.81
Fe ₂ O ₃	1.56	1.55	1.15	3.80	2.19	1.17	1.08
FeO	1.76	1.53	2.85	not det.	not det.	0.82	2.71
MnO	0.16	0.40	0.23		0.13		0.15
MgO	0.14	0.22	0.40	1.27	0.04	0.13	0.72
CaO	1.00	1.36	1.49	1.68	0.81	1.44	1.55
Na ₂ O	7.08	5.95	5.00	7.23	5.28	4.92	5.76
K ₂ O	4.78	5.36	5.97	5.12	5.60	5.78	5.62
H ₂ O +	0.05	0.82	0.39	0.71	1.22	0.05	0.70
H ₂ O —	0.05		0.19				
P ₂ O ₅	0.04	0.02	0.13				0.09
CO ₂		None	Trace?				
ZrO ₂	0.08		0.11				
SO ₃	None	0.06	None				
Cl		0.04	0.05				
F			0.08				
BaO		None	0.03				
SrO			Trace				
FeS ₂			0.07				
Li ₂ O			Strong trace				
Sum	101.61	99.86	100.18	100.40	99.54	99.84	100.00
Specific gravity			2.659				

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- I = Augite syenite, nordmarkite, type phase (nordmarkose), Cuttingsville, Vt., C. D. Test, analyst.
 II = Nordmarkite (nordmarkose), Shefford Mountain, Quebec.
 III = Hornblende-biotite nordmarkite (phlegrose), Ascutney Mountain, Vt.
 IV = Nordmarkite (laurvikose), Anneröd, Norway.
 V = Akerite (phlegrose), between Thinghøvd and Fjellebua, Norway.
 VI = Quartz nordmarkite (toscanose), Halasag, Ditro, Siebenbürgen, Hungary.
 VII = Nordmarkite (average of 7 analyses, R. A. Daly).

II	Quoted from	Dresser, J. A., Amer. Geologist, vol. 28, p. 209, 1901.
III	“ “	Daly, R. A., U. S. Geol. Surv., Bull. 209, p. 59, 1903.
IV, V, VI	“ “	Washington, H. S., U. S. Geol. Surv., Prof. Paper 14, pp. 171, 195, 203.
VII	“ “	Daly, R. A., “Igneous Rocks and Their Origin”, p. 22.

The rock is nordmarkose, with the following norm:

Quartz	5.40	Hypersthene	.79
Orthoclase	28.36	Magnetite	2.32
Albite	59.74	Ilmenite	.30
Anorthite	1.67	Water, etc.	.22
Diopside	2.85		
			<hr/> 101.65

Hand specimens of the Cuttingsville augite syenite and the Ascutney Mountain nordmarkite very closely resemble each other and the Shefford Mountain nordmarkite. The resemblance is so close that hand specimens of the three are practically indistinguishable. Although the Cuttingsville rock contains the highest per cent of silica, thin sections of the Ascutney rock seem to show the most quartz, and thin sections of the Cuttingsville rock the most augite. The Shefford Mountain rock, judged in this manner, appears to be intermediate between the other two.

The Cuttingsville augite syenite has a *quartz-bearing phase*. It is apparently quite subordinate to the type phase, and occupies no well-defined area. Generally it is developed as a selvage, a few feet in width, along the contact of the augite syenite and the country rocks. It is usually finer-grained than the type phase, but the quartz is always distinctly visible, sometimes forming a considerable part of the rock. With diminution of the proportion of dark silicates, the finer-grained rock becomes quite aplitic. Some of it, of aplitic or paisanitic habit, occurs

in narrow dikelets and streamers cutting the type and coarser phases.

Green hornblende, with accessory quartz, is notable in certain thin sections. Part of the hornblende is probably secondary. The presence of hornblende and quartz allies this phase to the Ascutney Mountain nordmarkite, and less closely to the Shefford Mountain nordmarkite.

Near the summit of the south knob of Granite Hill a *porphyritic* syenite, tentatively mapped as nordmarkite (5, fig. 1), is closely associated with essexite not far from the country-rock contact. Apparently it is a border development of the eruptive body, and of small extent.

In the zone between nordmarkite and essexite, on the upper north slope of the north knob of Granite Hill, the nordmarkite becomes increasingly biotitic. Some of it also carries roughly idiomorphic hornblende and plagioclase, which are sometimes arranged in flow lines. The rock grades from medium-grained to fairly fine, and from granitic to porphyritic. It becomes so much like the adjoining essexite that the actual contact is somewhat indistinct. The contact rock is perhaps best classified as an essexite-nordmarkite hybrid.

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Essexite porphyry.—The apophyses from the essexite are generally porphyritic. Petrographically this essexite porphyry has no special peculiarities worthy of detailed statement. Hornblende and biotite, alone or together, are the chief phenocrysts.

Nephelite syenite.—As already noted, nephelite syenite forms dike-like bodies in the hornblende-biotite syenite of the quarry (Q 2, fig. 1).

Syenite porphyry.—Pulaskite porphyry and nordmarkite porphyry are developed at the borders of both the pulaskite and nordmarkite masses. An account of porphyritic phases of pulaskite and nordmarkite has been given. These phases pass into pulaskite porphyry and nordmarkite porphyry, at contacts and in apophyses, by increase of groundmass.

Some of the pulaskite porphyry is apophysal from the main pulaskite body, but other masses form dikes which seem to be distinctly later intrusions. Two or more of

these later dikes are exposed in the pit (P, in fig. 1) south of the quarry (Q 2, fig. 1). They appear to cut essexite and probably also biotitic pulaskite.

Zircon-rich pulaskite porphyry.—At the foot of the eastern slope of the north end of Granite Hill, about 200 feet downstream from a short tunnel (T, fig. 1), a dike of coarse trachytic rock is exposed from the bank of Mill River 40 feet up the steep slope. The dike cuts green, quartz-bearing augite syenite, which is brecciated at the lower contact and receives branch dikelets. The main dike has a thickness of approximately 12 feet, and dips about 50° S. E. About 125 feet upstream an irregular dike of similar rock, with a maximum width of 15 feet, extends 10 feet up the slope. Downstream from the main dike, near a dam, similar rock is again exposed. All three of these exposures may belong to the same dike.

The rock of the main dike shows strong contact chilling. The sections studied are of the coarse-grained, middle phase. These specimens show broad, half-inch tablets of gray feldspar, slender prisms and small grains of black pyroxene, and less frequent, small, hexagonal and irregular flakes of black mica, in a fine to medium-grained mass of feldspar, black pyroxene, and black mica. Feldspar greatly predominates, giving the rock its light gray color.

Thin sections show roughly idiomorphic feldspar and pyroxene in a granular mass, including feldspars, pyroxene, biotite, magnetite, zircon, titanite, apatite, little hornblende, and possibly nephelite (or sodalite), corundum, and fluorite. About 90 per cent of the rock is feldspar, chiefly anorthoclase, with orthoclase, microperthite, and subordinate oligoclase (Ab_6An_1). Between and penetrating the feldspar are irregular areas of zeolites or other secondary minerals, which may have been derived from nephelite or sodalite. Augite, occasionally with outer zones of ægirite-augite, or ægirite, is the principal colored mineral.

Mineralogically the rock is a zircon-rich pulaskite porphyry. Its complete chemical analysis was not attempted. Dr. H. E. Merwin, however, tested it for zirconia in order to check the microscopic evidence of abundant zircon. He found sufficient zirconia for at least 1 per cent of zircon. He also determined the percentages of soda and potash, as, respectively, 7.32 and 4.81.

Aplite.—Narrow aplitic dikes of paisanitic quality cut the coarse and medium phases of the augite syenite. They also penetrate, for short distances, the country gneisses to the west.

Tinguaite.—The locations of tinguaite dikes are shown in fig. 1. At the foot of the eastern slope of the south knob of Granite Hill, along the bank of Mill River, a complex of syenitic and essexitic phases is cut by numerous narrow dikes of syenite-porphry, tinguaite, and camptonite. A tinguaite dike (D, fig. 1) towards the upstream end of the exposure carries remarkably fresh rock, selected for chemical analysis. The dike, about one foot wide, dips 80° N. N. W.

The hand specimen has a medium-gray color, a dense, fine-grained texture, and a superficial resemblance to blue quartzite, though of duller luster. A few, small phenocrystic laths of feldspar are discernible. In the groundmass, nephelite is sufficiently abundant to yield much gelatinous silica when the powdered rock is treated with hydrochloric acid.

The thin section shows well-formed phenocrysts of anorthoclase and micropertthite in a fine, granular groundmass. The groundmass carries some fairly distinct laths of feldspar and prisms of pyroxene. The remaining feldspar, pyroxene, and most of the other minerals are allotriomorphic. Orthoclase and nephelite appear in roughly equal amounts, with plagioclase (albite) apparently somewhat less than either. Reckoning groundmass and phenocrysts together, 90 per cent or more of the rock is feldspar and nephelite. The nephelite is seen to enclose minute orthoclase crystals. There are occasional grains of cancrinite. A colorless mineral in irregular and veinlike patches is probably sodalite; a little chlorine reported in the analysis may thus be accounted for. Pyroxene is represented by two varieties. One is pleochroic, in colors from yellowish or brownish to green. Extinction angles run up to 20°. These characters, together with the proper elongation, indicate an ægirite-augite. The other, less abundant, is a very pale or colorless variety, apparently diopside. The accessories are magnetite, titanite, zircon and rare apatite.

The chemical analysis of this tinguaite (miaskose) and its parallels are stated in the accompanying table:

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	I	II	III	IV	V	VI	VII
SiO ₂	57.64	55.68	54.22	55.06	55.46	56.58	55.02
TiO ₂	0.15	0.60	0.38		0.20		0.36
Al ₂ O ₃	23.31	20.39	20.20	23.29	24.49	19.89	20.42
Fe ₂ O ₃	1.22	2.10	2.35	3.29	2.63	3.18	3.06
FeO	0.55	1.95	1.02	not det.	1.06	0.56	1.82
MnO	0.10	0.31	0.19		Trace	0.47	0.22
MgO	0.22	0.80	0.29	Trace	0.05	0.13	0.59
CaO	0.67	1.92	0.70	1.46	0.92	1.10	1.67
Na ₂ O	10.48	9.18	9.44	6.76	9.78	10.72	8.63
K ₂ O	5.09	5.34	4.85	8.86	5.16	5.43	5.38
H ₂ O +	0.24	1.50	5.57	1.08	0.07	1.77	2.77
H ₂ O —	0.02		0.42				
P ₂ O ₅	Trace	0.06	0.11		Trace		0.06
CO ₂	None		Trace				
ZrO ₂	0.12						
SO ₂	Trace		None				
Cl	0.02		Trace				
F	0.06		Trace				
Cr ₂ O ₃	None						
BaO	None		Trace				
SrO	Trace						
FeS ₂	0.08						
Fe ₇ S ₈	0.05						
Li ₂ O	None						
Sum	100.02	99.83	99.74	99.80	99.82	99.83	100.00

I = Tinguaitite, type phase (miaskose), Cuttingsville, Vt., H. E. Merwin, analyst.

II = Tinguaitite (laurdalose), Brome Mt., Quebec.

III = Aegirite tinguaitite (miaskose), Southboro, Mass.

IV = Leucite tinguaitite (beemerose), Serra de Tingua, Brazil.

V = Tinguaitite (miaskose), Gy. Szt. Miklos, Czanod, Siebenbürgen.

VI = Tinguaitite (laurdalose), Hedrum, Norway.

VII = Tinguaitite (average of 15 analyses, R. A. Daly).

II	Quoted from	Dresser, J. A., this Journal, vol. 17, p. 355, 1904.
III	“ “	Clarke, F. W., U. S. Geol. Surv. Bull. 591, p. 35, 1915.
IV, V, VI	“ “	Washington, H. S., U. S. Geol. Surv., Prof. Paper 14, pp. 207, 213, 295.
VII	“ “	Daly, R. A., “Igneous Rocks and Their Origin,” p. 35.

The rock is a miaskose, with the following norm:

Orthoclase	30.02	Diopside	1.08
Albite	36.68	Magnetite	1.86
Anorthite	1.96	Ilmenite	.30
Nephelite	27.55	Water, etc.	.59
		100.04	

Comparison with the Brome Mountain tinguaitite shows one more proof of general chemical similarity between the Monteregean eruptives and those at Cuttingsville.

The Southboro, Mass., tinguaita (also miaskose) contains ægirite, while the Cuttingsville rock carries ægirite-augite. The Brazilian tinguaita is the classic example from Serra de Tingua, the type locality. It differs from the Cuttingsville rock in bearing leucite.

Camptonite.—Camptonite dikes, not quite as numerous as the tinguaita dikes (fig. 1), are associated most closely with essexite and nordmarkite.

Perhaps the most typical camptonite occurs in a dike a foot thick, exposed in the wall of a small, abandoned nordmarkite quarry (Q 5, fig. 1) on the lower north slope of Granite Hill. The rock is black and porphyritic, with a few scattered, flashing crystals of black hornblende, and more numerous, smaller tablets and masses of gray-white feldspar. One of the hornblendes is 2 centimeters long. An occasional grain of olivine also contrasts with the black, fine-grained groundmass. The thin section shows phenocrysts of augite, moderately basic plagioclase, brown hornblende, and serpentinized olivine. The groundmass is an aggregate of brown hornblende, plagioclase, augite, magnetite, and some pyrite.

In the more northerly of the two small eruptive areas north of Granite Hill (fig. 1) three camptonite dikes cut essexite or the country gneisses. One of the dikes, about 25 feet wide, carries many inclusions of gneiss, quartzite, syenite, and probably essexite. They are generally angular in shape and less than 1 cm. in diameter. The camptonite is porphyritic. The phenocrysts are brilliant, black hornblendes. They are usually under 2 cm. in length, though some reach 8 or 10 cm. A single large grain of serpentinized olivine appears in one specimen. The groundmass is dark gray, fine-grained, and dense.

Thin sections show the phenocrysts to be brown hornblende and, in smaller amount, zoned plagioclase, andesine to basic labradorite. There is some kaolinized orthoclase or micropertthite, probably xenolithic. Green pyroxene, more or less altered to actinolite and chlorite, also appears among the phenocrysts. The groundmass is chiefly composed of plagioclase laths, small prisms of hornblende and actinolite, and chlorite. Brown biotite, magnetite, apatite, titanite, ilmenite, and pyrite are accessory.

MINERAL DEPOSITS.

On Copperas Hill (fig. 5) large bodies of pyrrhotite, once mined as a source of copperas, have replaced limestone cut by tinguaitic dikes which appear to have played a determining part in the ore deposition. In this connection, the presence of pyrrhotite, as an accessory min-

FIG. 5.

FIG. 5. Copperas Hill, looking northeast. Dumps from open cuts in pyrrhotite deposit at right center.

eral in several of the rocks which have been described, is worth noting.

Molybdenite (M, fig. 1) occurs in syenite at its contact with gneiss on the crest of Granite Hill, a quarter of a mile north of the hornblende-syenite quarry. The molybdenite scales are of medium size, often thickly powdered, like the inclosing syenite, with yellow molybdenite. Apparently the deposit is too limited to warrant development.

GENERAL CONCLUSIONS

Emplacement of Eruptives.—Cross-cutting relations of the main eruptive body to the country rocks, the oval surface plan, and high contact dips, indicate that the

main eruptive body is a composite stock. It is certainly not a laccolith and probably not a chonolith. The two small eruptive areas north of the main body seem to be parts of a single, small, satellitic stock or chonolith, if not simply a northward prolongation of the main body, now separated in outcrop by fluvial and glacial deposits.

Comparison with other areas.—The general structure is comparable to that of Ascutney Mountain, not more than 25 miles distant, which is also a composite stock. There biotite granite and diorite appear in addition to types which almost duplicate certain of the Cuttingsville rocks.

Though the main Cuttingsville body has a rough concentric structure, its relations to country rock recall those of at least four stocks of the Monteregian Hills, Quebec, namely, St. Hilaire, Rougemont, Johnson (a neck?), and Yamaska Mountains. Of the other Monteregian masses, Shefford, Brome, and St. Bruno (Montarville) are composite and have been described as laccoliths, without compelling evidence.

In all of these hills, essexite is represented. In six (perhaps all) of them the essexite is associated with syenite. This association, combined with close mineralogical and chemical similarity to the Ascutney and Cuttingsville eruptives, renders the comparison doubly impressive.

Red Hill, N. H., a neighboring New England locality, furnishes another example of a small, composite syenite stock, described by Pirsson.⁴ The country rock is a granitic gneiss, and the eruptives include, in the order of eruption, nephelite syenite (umpteckite, foyaite), aplite, paisanite, bostonite, syenite porphyry, and camptonite. Chemical similarity of the Red Hill umpteckite and the Cuttingsville, Vt., hornblende-biotite syenite has been noted.

Essex county, Mass., the type locality for essexite, and Southboro, Mass, a tinguaita locality, are other examples of New England areas containing eruptives chemically related to certain of the Cuttingsville rocks.

The Cuttingsville area thus takes its place as one more of the known number of small alkaline intrusive bodies in the New England-Quebec region. Most of the Monte-

⁴L. V. Pirsson, this Journal, vol. 23, p. 257, 1907.

regian Hills lie west of the limit of Appalachian deformation, their intrusions penetrating practically undisturbed beds. The Cuttingsville and other New England examples are located in disturbed rocks, although themselves not notably affected by deformation.

Reference has already been made to the similarity of the Cuttingsville rocks to certain eruptive rocks of southern Norway.

Order of Eruption.—Field observation indicates that eruption of the plutonic types proceeded in the order usual with alkaline intrusions, namely from basic to acidic. Essexite was plainly the earliest intrusion. The syenites followed essexite in a succession not entirely clear. Nordmarkite was apparently the last. Hornblende-biotite syenite, with pulaskite, nephelite syenite (foyaite) and sodalite-nephelite syenite, probably came between essexite and nordmarkite in about the order given.

On the other hand, the syenites possibly constitute a single eruption, rather than a succession of intrusions. If the hornblende-biotite syenite is a simple differentiate, rather than a hybrid, it was the first of the syenites to separate.

The apophysal dikes conform, in a general way, to the same order of basic to acidic intrusions. Essexite porphyries were the earliest, some of them apparently truly apophysal from the essexite body, and others intrusive into it. Aplite was later than the nordmarkite. The syenite porphyries presumably came between essexite porphyry and aplite. Some of the pulaskite-porphyry dikes, however, cut nordmarkite, and may be even younger than aplite.

With the "complementary" dikes the order was reversed, the tinguaite dikes, which are relatively acidic, preceding the relatively basic camptonite dikes. Some of the tinguaite dikes are probably younger than all the plutonic types and the truly apophysal dikes. Others are possibly only tinguaitic phases of pulaskite porphyry and nordmarkite porphyry. The camptonite dikes may not all be of the same age. Some of them are the latest of all the intrusions.

Origin of the Magmas.—The Cuttingsville eruptives are clearly consanguineous; it may be reasonably inferred that all have come from a single parent magma.

No subalkaline rocks have been noted in association with the Cuttingsville eruptives. Yet that fact does not necessarily invalidate the hypothesis that the alkaline rocks are differentiates from modified subalkaline magmas. It might be assumed that an originally subalkaline magma was modified by desilication to produce the alkaline parent magma. The desilication may have resulted from the assimilation of limestone which outcrops in at least four different localities about the main eruptive body. More limestone may have been stopped from overlying beds since removed by erosion. Assimilation of hornblende gneiss, so abundant in the country rock series, may have increased the desilicating effect.

That syntexis of country rock has played a part in magmatic changes is to some extent supported by the frequent development of a quartzose selvage of syenite in contact with quartzose country rock, and by the occurrence of apparently primary calcite in certain of the dike rocks.

A highly important factor in the problem of the origin of the magma is the stock structure of the eruptive body. This structure implies a body of magma very much greater than that corresponding to the rocks directly visible at the present erosion surface. Stocks are generally assumed to be small projections from greater batholithic bodies. In any case, the exposed part of a stock is only a transverse section high up in the magma chamber. This condition renders assumptions regarding the nature of the original magma, before assimilation and gravitative differentiation had set in, highly speculative.

The exposed rocks of the stock have an average composition not far from that of a typical laurvikose. It is not unlikely that, owing to gravitative differentiation, the deeper rocks are more basic and mafic. This of course would increase the basicity of the stock as a whole and necessitate the assumption of a parent magma more basic than laurvikose. The essexite may represent nearly the chemical nature of the parent magma, suggesting, further, that the original, unmodified subalkaline magma was truly basaltic.

This view has much in its favor. It explains the eruption of essexite first as an extravasation of parent magma before very marked differentiation had set in. The succeeding, increasingly feldspathic eruptions mark

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stages in the advance of differentiation, possibly interrupted, and again renewed, by further assimilation of country rock.

LIST OF CHEMICAL ANALYSES.

	I	II	III	IV	V	VI	VII
SiO ₂	57.44	46.47	60.88	57.64		67.30	38.04
Al ₂ O ₃	21.60	16.86	20.75	23.31		17.44	13.50
Fe ₂ O ₃	.20	3.21	.63	1.22		1.56	6.21
FeO	2.62	7.72	1.13	.55		1.76	15.85
MgO	1.09	5.16	.17	.22		0.14	7.26
CaO	2.90	9.45	1.08	.67		1.00	12.42
Na ₂ O	7.36	4.20	6.35	10.48	7.32	7.08	3.21
K ₂ O	4.12	1.35	5.57	5.09	4.81	4.78	1.68
H ₂ O +	.58	.45	.88	.24		0.05	0.48
H ₂ O —	.03	.04	.03	.02		0.05	
CO ₂	.39	Trace	.61	None			
TiO ₂	.69	2.86	.35	.15		0.17	1.06
ZrO ₂	.02	None	Trace	.12		0.08	
P ₂ O ₅	.38	1.15	Trace	Trace		0.04	
SO ₃	None	None	None	Trace		None	
Cl	.07	.06	.18	.02			
F	.05	.10	.05	.06			
Cr ₂ O ₃	None	None	None	None			
MnO	.14	.23	.22	.10		0.16	1.21
BaO	.26	Trace	.02	None			
SrO	.04	.04	Trace	Trace			
FeS ₂	.15	.21	.61	.08			
Fe ₂ S ₃	.14	.08	.13	.05			
Li ₂ O	None	None	None	None			
Sum	100.27	99.64	99.64	100.02		101.61	100.92
Specific gravity	—						3.518

- I = Hornblende-biotite syenite (laurvikose), H. E. Merwin, analyst.
 II = Essexite (andose), H. E. Merwin, analyst.
 III = Sodalite-nephelite syenite (nordmarkose), H. E. Merwin, analyst.
 IV = Tinguaitite (miaskose), H. E. Merwin, analyst.
 V (partial) = Zircon-rich pulaskite porphyry, H. E. Merwin, analyst.
 VI = Augite syenite (nordmarkite, nordmarkose), C. D. Test, analyst.
 VII = Barkevikitic hornblende from hornblende-biotite syenite of analysis I, C. D. Test, analyst.