With Compliments of
Vernon F. Marsh

DEPARTMENT OF THE INTERIOR

# BULLETIN

OF THE

# UNITED STATES

# GEOLOGICAL SURVEY

# No. 107



THE TRAP DIKES OF THE LAKE CHAMPLAIN REGION

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[Bulletin No. 107.]

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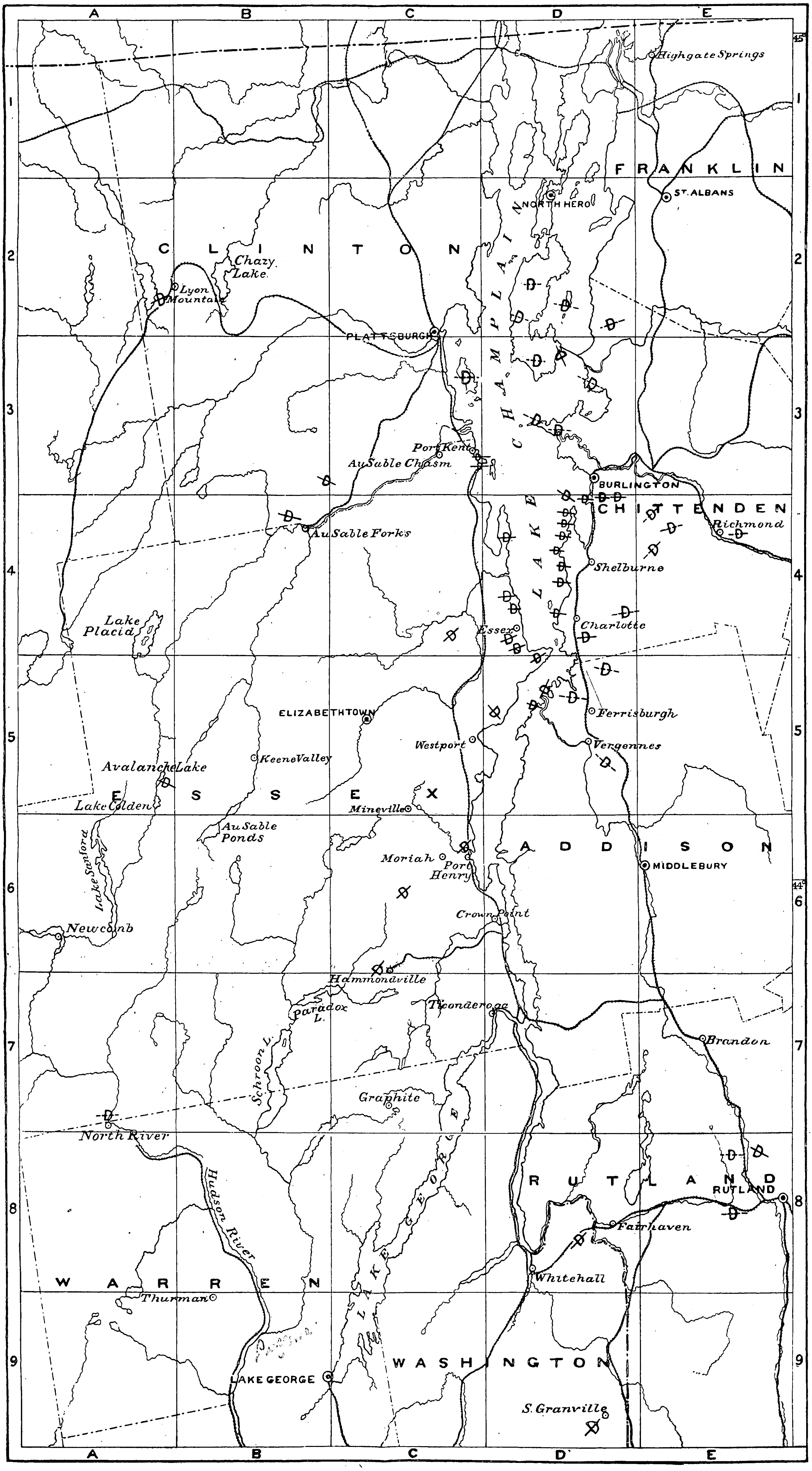


GENERAL MAP OF THE LAKE CHAMPLAIN REGION, SHOWING THE DISTRIBUTION OF THE DIKES.

DEPARTMENT OF THE INTERIOR

# BULLETIN

OF THE

# UNITED STATES

# GEOLOGICAL SURVEY

# No. 107

WASHINGTON
GOVERNMENT PRINTING OFFICE
1893

UNITED STATES GEOLOGICAL SURVEY

J. W. POWELL, DIRECTOR

# THE TRAP DIKES

OF THE

# LAKE CHAMPLAIN REGION

BY

JAMES FURMAN KEMP

AND

VERNON FREEMAN MARSTERS

WASHINGTON

GOVERNMENT PRINTING OFFICE

1893

# CONTENTS.

# ILLUSTRATIONS.

# LETTER OF TRANSMITTAL.

DEPARTMENT OF THE INTERIOR,
UNITED STATES GEOLOGICAL SURVEY,
DIVISION OF ARCHEAN GEOLOGY,
*Bainbridge, Ga., June 1, 1893.*

SIR: I have the honor to transmit herewith a paper by Messrs. J. F. Kemp and V. F. Marsters, relating to the trap dikes of the Lake Champlain region.

Mr. Kemp's field work was aided by a small amount of money from the Archean Division towards defraying a part of the expenses, and with the understanding that the results should be at the service of the U. S. Geological Survey.

I have the honor to be, sir, your obedient servant,

RAPHAEL PUMPELLY.

Hon. J. W. POWELL,
*Director U. S. Geological Survey.*

# THE TRAP DIKES OF THE LAKE CHAMPLAIN REGION.

BY JAMES F. KEMP AND VERNON F. MARSTERS.

## GENERAL TOPOGRAPHICAL REVIEW OF THE REGION.[1]

Lake Champlain extends somewhat more than 100 miles along the northeastern border of New York, between it and Vermont. It lies in the valley formed by the Green Mountain range on the east and the Adirondacks on the west. The foothills of the latter run down in one or two places to the water, but in general the main ridges are situated from 10 to 25 miles back in the interior. On the Vermont side, the surface rises from the lake in a gradual ascent to the summits of the Green mountains, 20 miles or more away. The slopes are more even and less rugged than those in New York, but in both cases their aspect is picturesque and beautiful in the highest degree. (See map, Pl. I.)

The lake itself is a very narrow body of water for 40 miles above Whitehall—in no place over a mile wide, and in general not over a quarter of that width. Opposite Port Henry and at the point on which stands the prerevolutionary Fort Frederick it offsets sharply to the west, and then resumes with increasing width its northerly course. In the widest portion, which is just north of Burlington, 10 miles of clear water intervene between shore and shore. The northern end contains many islands, both large and small. The deepest portion is opposite Essex, and reaches 400 feet. The depth of the northern part is, in general, 200 to 300 feet; but south of Fort Frederick it is very much less.

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[1] The field work for the accompanying paper was done in the summers of 1889 and 1890, by J. F. Kemp and V. F. Marsters. In 1890, A. S. Eakle accompanied them. The determinations, the composition of the paper, and the maps are the work of J. F. Kemp, but all possible aid was given by Mr. Marsters, who properly figures as joint author. The authors are under great obligations to Mr. A. S. Eakle, of Cornell University, and to Profs. G. H. Perkins, of Burlington, Vt., and H. Seely, of Middlebury, Vt., and to Mr. F. L. Nason, now of Missouri, for aid which is gratefully acknowledged.

## GENERAL GEOLOGICAL REVIEW.

The lake lies not far from the contact of the Archean crystalline rocks of the Adirondacks and the later sedimentary strata to the east of them. For 5 miles above Whitehall[1] the Archean forms both shores, and extends on the New York side nearly 10 miles farther, but yields to the Cambrian in Vermont. These later sedimentary rocks (Cambrian and Lower Silurian) form both shores as far as Port Henry, being broken by Mount Defiance (Archean) at Fort Ticonderoga, and by one or two Archean bluffs near Crown Point. From Port Henry to and including Split Rock the Archean forms the New York side, the Cambrian and Lower Silurian make up the Vermont shore. These latter continue in Vermont up to the national boundary. From Split Rock to the foot of Willsboro bay, including Willsboro point, the sedimentary rocks prevail, but then the Archean again comes in and continues to Port Kent. North of Port Kent the Cambrian and Lower Silurian strata constitute both the mainland and the islands. Thus the Archean appears on the Vermont side only at the extreme southern end, and it is apparent that the greater part of the lake lies within the limits of the Cambrian and Lower Silurian.

The Archean rocks along the western shore consist of the labradorite-hypersthene rock (variously called labradorite or hypersthene rock, hypersthene-fels, norite, anorthosite, and gabbro) characteristic of the Adirondacks; of gneisses which mark the iron-bearing terrane and of crystalline limestones often containing much serpentine. The relations of these several members have never been satisfactorily made out. Ebenezer Emmons[2] merely described them as "primary" and mentioned the three types referred to above, but did not discuss their relations in time. Since the application of the term Laurentian by Logan[3] in 1852 to similar rocks in Canada, it has been generally used for the Adirondacks. Still later the term Labradorian and subsequently the name Upper Laurentian were given by Logan to the labradorite rocks and they were considered to be later than the gneisses. Hunt, on the resemblance of the labradorite rock to the norites described by Esmark from Sweden, coined the name "Norian" for them and regarded them as later than the Laurentian. James Hall[4] has argued that the limestones are later than the other Archean rocks and that they belong be-

[1] For the geography, reference may be made to the large map, Plate I, primarily drawn to show the distribution of the dikes.

[2] Report on the Second District of the New York State Survey, 1842.

[3] Compare in this connection C. H. Hitchcock, Am. Geologist, April, 1890, p. 197; also J. F. James, do., Jan., 1890, and Aug., 1890, p. 133; J. Marcou, July, 1890, p. 64.

[4] James Hall: Note upon the geological position of the serpentine limestone of northern New York and an inquiry regarding the relations of this limestone to the Eozoon limestones of Canada. Amer. Asso. Adv. Sci., 1876, p. 298; Amer. Jour. Sci., ser. iii, vol. XII, p. 298.

tween them and the Potsdam. Charles E. Hall[1] has made the following somewhat tentative division based on very limited field work and having especial reference to the iron ores: (*a*) Lower Laurentian magnetite Iron ore series (i. e., the rocks called gneisses above); (*b*) The Laurentian sulphur ore series; (*c*) The limestones and the Labrador or Upper Laurentian series. Division *c* is said to be certainly later than *a*, while the relations of *b* are uncertain. It must be confessed that the field work done in the region since the time of Emmons has not been such as to gain unreserved confidence for any classification yet offered, and the current statements of the relative age of the norites and gneisses are to be received with great caution. The norites[2] may be eruptive, or may be metamorphic; perhaps in instances each view is correct, but if they are a great intruded mass or masses in the midst of older gneisses it is most remarkable that no dikes and radiating apophysæ have yet been recorded.

The sedimentary rocks of the region are included in the early members of the Paleozoic up to and embracing the Utica slate. No mention is here made of the Champlain clays and Quaternary deposits as they have no connection with the dikes. The subdivision of the Paleozoic rocks on the New York side is less difficult than in Vermont, where extensive metamorphism consequent on the elevation of the Green Mountain range has obscured their true relationships. Emmons recognized the Potsdam sandstone, the Calciferous sandrock, the Chazy limestone, Trenton limestone, and Utica slate. While the same rocks largely occur in Vermont their identification has been a matter of much controversy. Other beds also come in. President Hitchcock and his assistants on the Vermont Survey made the following division (1861): Metamorphic rocks, Potsdam sandstone, Calciferous sandrock, Chazy, Birdseye and Black river limestones, Trenton, Utica, Hudson river, Red sandrock, Quartz rock, Georgia slates, Talcose conglomerate, Eolian limestones; Talcoid schist, with limestone, Upper Helderberg. But the question of the relative age of these is handled very gingerly or omitted altogether.

To the south some of these formations entered largely into the Taconic controversy. Since the publication of the results of the Vermont state survey a number of observers have added greatly to our knowl-

[1] Chas. E. Hall: Laurentian magnetite iron ore deposits in northern New York. 32d Ann. Rep. N. Y. State Cabinet of Natural History, p. 133, 1884.

[2] On the lithology of the norites from a limited area (the Keene Valley), see A. R. Leeds: Notes on the lithology of the Adirondacks, 30th Annual Report of the N. Y. State Cabinet of Natural History, p. 79, 1877; also, Amer. Chemist, vol. 7, p. 328, Mar., 1877. The paper is reviewed by A. R. C. Selwyn in the Rep. of Progress of Geol. Survey of Canada, 1877–'78. On the serpentinous limestones, see G. P. Merrill: Ophiolite of Thurman, Warren Co., N. Y., with remarks on the Eozoon Canadense, Amer. Jour. Sci., iii, ser., vol. XXXVII, p. 189. Port Henry is also mentioned.

edge, notably Sir Wm. E. Logan,[1] the Rev. Augustus Wing,[2] Prof. Hitchcock,[3] Prof. Dana,[4] Profs. Brainerd and Seely,[5] of Middlebury; Prof. Whitfield, and Mr. C. D. Walcott.[6] The Rev. Mr. Wing discovered fossils in many beds generally metamorphosed and enabled a connection to be made with well-recognized beds farther South. Mr. Walcott has much enlarged the number of fossiliferous localities and on a paleontologic basis has made the Cambrian of greater importance. Thus the red sandrock so important near Burlington, and containing many dikes, is now put well down in the Cambrian, although first placed by Emmons in the Potsdam, then by Hitchcock in the Medina, but later also in the Potsdam. The discovery as well of fossils at Fort Cassin by Messrs. Brainerd and Seely and their identification by Prof. Whitfield, together with much careful and praiseworthy stratigraphical work by the former, have shown the great importance of the Calciferous and its extended development. Full accounts of this will be found in the papers cited below. Several other writers (Hunt,[7] Marcou,[8] J. B. Perry,[9] and the Canadian geologists) have from time to time worked in the region and have written minor contributions, but no other work has yet been published commensurate with those cited.[10] Prof. Pumpelly, under the

[1] W. E. Logan: The Quebec Group. Geol. of Canada, 1863, p. 225.

[2] J. D. Dana: An account of the discoveries in Vermont geology of the Rev. Augustus Wing, Am. Jour. Sci., ser. iii, vol. XIII, pp. 332 and 405, and vol. XIV, p. 36.

[3] C. H. Hitchcock: Description of geological sections crossing New Hampshire and Vermont. Concord, N. H., 1884. Amer. Jour. Sci., ser. iii, vol. XXIX, p. 66. Bull. Amer. Mus. Nat. Hist., vol. I, p. 155.

[4] J. D. Dana: On Staurolite schist and Green Mountain gneiss of the Silurian age. Amer. Asso. Ad. Sci., vol. XXII, p. 25, 1873.

——Note on the age of the Green mountains. Amer. Jour. Sci., ser. iii, vol. XIX, p. 191.

Also many papers on the Taconic controversy in the last fifteen or twenty years of the Amer. Jour. Science.

[5] E. Brainerd and H. M. Seely: On the Geology of the east shore of Lake Champlain. Bull. Amer. Museum of Nat. Hist., No. 8, p. 297, Dec. 28, 1886. The Calciferous Formation in the Champlain valley, loc. cit., vol. III, No. 1, June, 1890, same journal.

——The marble border of New England, Middlebury Historical Society, p. 2, vol. I. A very excellent short sketch of the geology of western Vermont is given on p. 9.

——The original Chazy rocks. Amer. Geol., vol. II, p. 323. The Chazy formation in the Champlain valley, Proc. Geol. Soc. Amer., p. 293, vol. II.

[6] C. D. Walcott: Geological age of the lowest formations of Emmons's Taconic System, Proc. Phil. Soc. of Washington, Jan. 15, 1887. Amer. Jour. Sci., ser. iii, vol. XXXIII, p. 153. Correlation paper on the Cambrian. Bulletin 81, U. S. Geol. Survey.

[7] T. S. Hunt: On some points in the geology of Vermont. Amer. Jour. Sci., ser. ii, vol. XLVI, p. 222.

[8] J. Marcou: The Taconic rocks of Lake Champlain. Amer. Jour. Sci., ser. iii, vol. XXII, p. 321.

[9] J. B. Perry: A point in the geology of Western Vermont. Amer. Jour. Sci., ser. ii, vol. XLVII, p. 341.

[10] J. F. Kemp: Brief review of work hitherto done on the geology of the Adirondacks. Trans. N. Y. Academy of Sciences, Oct., 1892.

direction of the United States Geological Survey, has been prosecuting studies of the metamorphic rocks which are yet to appear. The details of local geology so far as they concern the dikes will be found scattered through the subsequent pages.

## THE DIKES.

### GENERAL DISTRIBUTION.

The dikes pierce all the formations mentioned in the preceding introduction up to and including the Utica Slate. Their general distribution is shown on the map (Pl. I), which exhibits the region covered by our fieldwork. The dikes are seen to occur as far south as Granville, Washington county, N. Y., but others are mentioned in the Vermont reports from one or two points still further south. The most southerly one described in this paper is from Dorset mountain (called also Mount Eolus), in the town of Dorset, Vt., and lies just below the southeastern corner of the map.[1] A dike is also recorded in the Vermont Reports (vol. II, p. 588) from South Vernon, which is the extreme southeastern township of the state, and others are mentioned from Mount Holly,[2] which lies east of the limits of the map. South of Vermont, in western Massachusetts, but one dike has been mentioned. This is in the Hoosac mountain near the Vermont state line.[3] The dikes are well developed at South Granville, N. Y., (9D)[4] and will be found described in subsequent pages; again near Whitehall and Rutland[5] they come to the surface, but north of this point for some distance they have not been noted.

The most southerly dike recorded in New York is in gneiss, in the range of hills west of Glens Falls.[6] This would be below 9C of the map. Another is mentioned on the road from Glens Falls to Caldwell, and another (8A) from near Johnsburg. On the Hudson river above this last point a dike has been found by F. L. Nason, near the Natural Bridge north of the town of North River, specimens of which have been kindly given us by Mr. Nason. Four or five dikes cut the magnetite beds

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[1] See Fig. 230, p. 587, of Vol. II, Geology of Vermont. We are indebted for the specimen to Prof. H. M. Seely, to whom, for this and much other assistance, grateful acknowledgments may here be made.

[2] Geology of Vermont, Vol. II, p. 586. Also F. L. Nason. A new locality for the camptonite of Hawes and Rosenbusch; Amer. Jour. Sci., ser. iii, Vol. XXXVIII, Sept., 1889. We are indebted to Mr. Nason for chips, but learned subsequently that Dr. J. E. Wolff had already been investigating the Mount Holly dikes and their passage into amphibolites, so that no further mention of them is made here.

[3] R. Pumpelly: The relation of Secular Rock-Disintegration to certain transitional Schists; Proc. Geol. Soc. of Amer., Vol. II, 1891, p. 209.

[4] The figures and letters refer to the squares ruled on Plate I.

[5] J. F. Kemp and V. F. Marsters: Camptonite dikes near Whitehall, N. Y.; Amer. Geologist, Vol. IV, p. 97.

[6] E. Emmons: Geology of Second District, New York State Survey, p. 184. In 1893 James Hall and N. H. Darton found one at Saratoga.

at Hammondville (7C), and others occur at Roe's spar bed,[1] several miles northeast. Near Port Henry[2] they are numerous, and again at Mineville (6C) one or two cut the magnetite beds. Several others intersect the Archean rocks along the shore above Westport (5D), and numbers pierce the cliffs near Split Rock. On the Vermont shore opposite and south of this point the Cambrian and Lower Silurian strata are plentifully seamed by them, and the area of chief igneous activity extends on both sides of the lake to the latitude of Plattsburg. The principal centers are Pottier's point (more commonly called of later years Shelburne point), just below Burlington (4D); Cannon's point, just south of Essex, N. Y.; and Trembleau point, below Port Kent (3D). Special maps of each of these, on a large scale, are given later. Not a few are also known in the islands in the northern portion of the lake. (See Pl. II and Figs. 4, 5, and 9.)

In addition to these points dikes are known in the Archean norite of Boquet mountain (4C), three miles west of Essex; in the iron mines of Palmer hill,[3] Au Sable Forks (4B); at the Arnold mines at Ferrona; and to the north in the Chateaugay mines at Lyon mountain, Clinton county (2A). Several have been described by A. S. Eakle, from Chateaugay lake, in American Geologist for August, 1893.

A great dike was early recorded as dividing Mount Avalanche from Mount Colden[4] (5A) in the heart of the Adirondacks. This we have visited, but the description will be found elsewhere published. It is not a dike but a shear-zone along a line of faulting and does not belong in this paper.[5]

It will be seen from this brief outline that the dikes are very widespread. It is not to be supposed that more than a small portion of those away from the lake shore have been found, as the thick vegetation conceals exposures. It is worthy of remark that hardly a magnetite bed has been opened up which is not cut by them, and while one would hesitate to assert that the rocks in general are as plentifully intersected, the inference is unavoidable that they are very frequent, and it is by no means unlikely that the extended igneous action which gave rise to them may have been an important factor in the metamorphism of the

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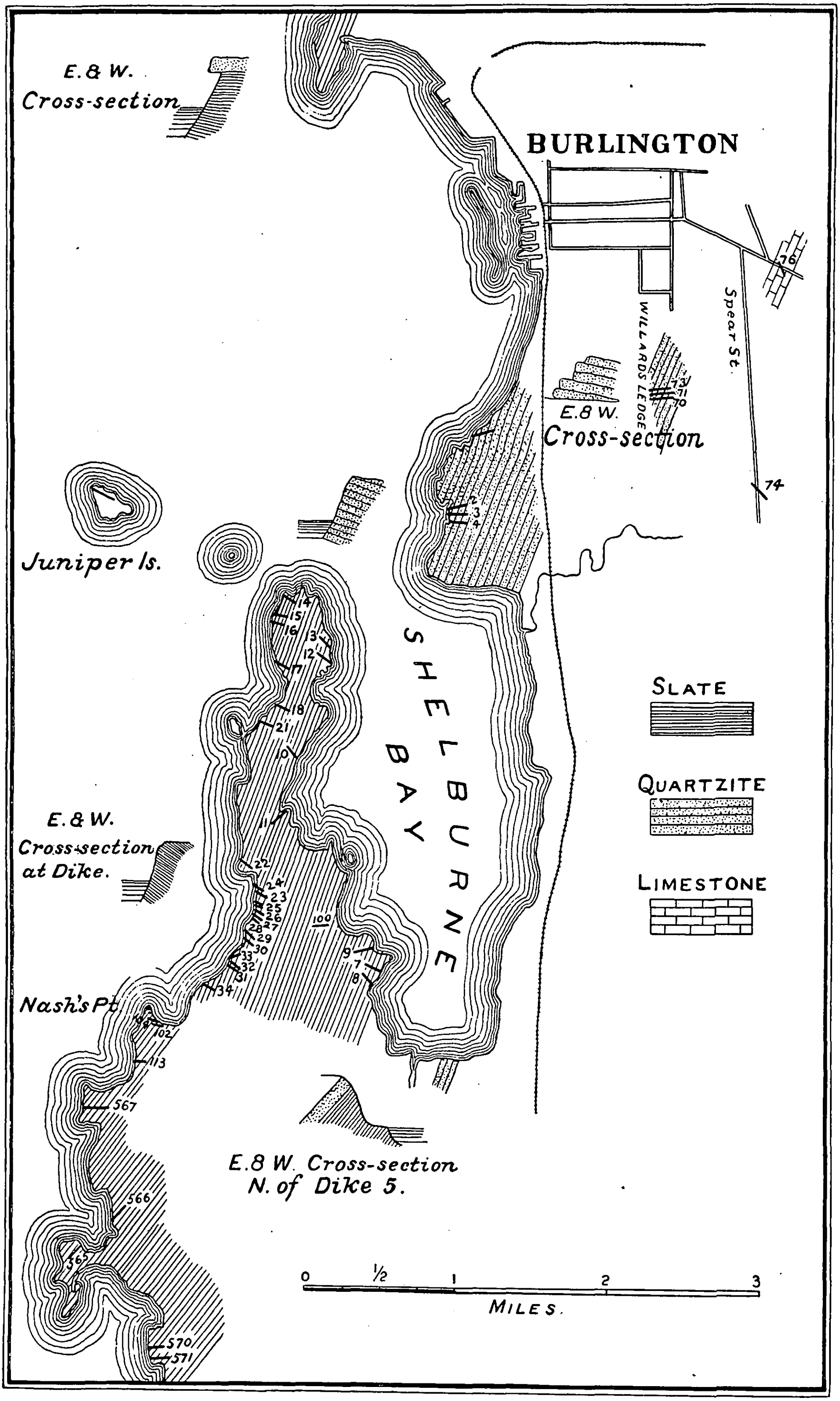
[1] J. F. Kemp: Notes on the minerals occurring near Port Henry, N. Y.; Amer. Jour. Sci., ser. iii, Vol. XL, July, 1890, p. 62.

[2] Geology of New York, Second District, p. 264; Tenth Census, Vol. XV, p. 115.

[3] Several are recorded by Emmons in First Annual Report, Second District New York State Survey, 1837, pp. 136, 137. See also Final Report, Second District New York State Survey, 1837, p. 299. B. T. Putnam, Tenth Census, Vol. XV, p. 118. J. F. Kemp, Amer. Jour. Sci., ser. iii, Vol. XXXV, p. 332.

[4] W. C. Redfield. Some account of two visits to the mountains in Essex county, N. Y., 1836-'37, with a sketch of the northern sources of the Hudson.—Amer. Jour. Sci., ser. i, Vol. XXXIII, p. 301. See also First Annual Report, New York State Survey, 1837, p. 131; Second Annual Report, New York State Survey, 1838, p. 223, and E. Emmons's Final Report on Second District, New York State Survey, 1837, p. 215. The two peaks are called together Mount McMartin.

[5] J. F. Kemp. Great shear-zone at Avalanche lake in the Adirondacks.—Amer. Jour. Sci., Aug., 1892.




DIKES AND STRATIGRAPHY AT SHELBURNE POINT, NEAR BURLINGTON, VERMONT.

region. The records of the west side of the Adirondacks are less complete, and our reading has discovered no mention of dikes; but, on analogy, it would seem as if they must be present. A bowlder has been found in the drift at Aurora, N. Y., by Prof. Freley, of Wells college, which is an excellent fourchite,[1] as the term is here employed and which probably came from the western Adirondacks.

## GENERAL MICROSCOPIC CHARACTER AND FIELD OCCURRENCE.

The dikes are formed by two strongly contrasted kinds of rock, the one, feldspathic porphyries or trachytes, which are called bostonite in this paper, the other dark basic rocks, which under the microscope are subdivided as diabases, camptonites, monchiquites, and fourchites. Both kinds occur closely associated in the same districts. In one instance, on Nash's point, as first announced by Zadock Thompson,[2] the basic dikes are unquestionably the older. The bostonite is known only along the shores of the lake in D4 and D5, and to the east in E4, where one dike is recorded near Hinesburg.[3] The dikes run from 2 feet to 40 feet in width and are prevailingly vertical. At Nash's point a dike has been turned aside from its vertical course and forms an interbedded sheet. In two places the masses are of greater size than could be described as dikes and form in the one case a laccolite, in the other a knob or eroded laccolite that covers considerable territory. Thus, just southeast of the railway station at Charlotte (D4) is a knob several acres in extent, and across the lake at Cannon's point, a mile and a half south of Essex (D4), is another flow that extends an eighth of a mile or more along the shore and runs back a mile or two inland. Its limits are not easily traced on account of overlying soil and vegetation, but its extent is considerable, and it is apparently an interbedded sheet or laccolite. The dikes inclose at times masses of the underlying rocks, and may even consist essentially of a breccia of slate with a cement of porphyry.

In the same region with the bostonite, but extending far beyond its limits, are the basic dikes. Along the shores of the lake in 4D and 5D they alternate more or less with the bostonite. They are in general narrower, but may rise as high as twenty feet. They never form anything but a dike, cutting sharply the bedding of the walls. Faulted dikes have been recorded by Z. Thompson[4] from Clay point, Colchester D3, and from the bed of the Winooski river, at Hubbell's falls, east of Burlington. The faults amount only to a few feet (three feet at Clay point). This general undisturbed character of the dikes is a fact of great importance, and will be again referred to in discussing the time

[1] See Petrographical notes, by J. F. Kemp, Trans. N. Y. Acad. Sci., June, 1892.

[2] Zadock Thompson: Appendix to Thompson's History of Vermont, Burlington, 1853, p. 53.

[3] E. Hitchcock, sr.: Geology of Vermont, Vol. II, p. 585.

[4] Z. Thompson: Appendix to Thompson's History of Vermont, p. 53.

of intrusion. The dike at Willard's ledge in the city of Burlington has been found by us to contain fragments of norite, but elsewhere the basic dikes are not prolific in inclusions, far less so than the bostonite. They occasionally show a tendency to separate into columns with axes normal to the cooling surfaces, as may be seen in the one figured in the Vermont Report, volume II, p. 587, from Mount Eolus and in one noted by us at the end of Pottier's point.

## PETROGRAPHIC DESCRIPTION.

### THE BOSTONITE (PORPHYRY TRACHYTE) DIKES.

The name bostonite has recently been proposed by Hunter and Rosenbusch,[1] as applicable to a dike rock of trachytic habit that is now known to be quite widely associated with eleolite-syenite and the basic dikes so commonly seen with it. But the bostonite also occurs in regions where the connection with eleolite-syenite is not apparent. The term is based on the descriptions of the porphyries near Boston by Wadsworth, Diller and others, and is proposed in connection with studies of Brazilian rocks. While we feel conservative as to the introduction of new names into the already overburdened nomenclature of petrography and consider even the creation of a separate group of the dike rocks coordinate with the old groups, plutonic and volcanic (or by whatever later names they may be called), as open to grave objections, yet the convenience of such grouping is in many respects great, and if one does not infer too much from it, it may be used with justification.

The bostonites here described have a prevailing light tint, which is usually a creamy or brownish white, but which is also in instances a light chocolate. The rocks have a general rough and granular feel and a fracture very like typical trachyte. One specimen from Ball's bay, near Fort Cassin, given us by Prof. Seely, is macroscopically lithoidal, and has even to the naked eye a rude flow structure, like lithoidal obsidian. Phenocrysts are in general not especially marked, the less so because the wide-spread alteration of the exposures makes fresh material difficult to obtain. They are at times present, and when fresh exhibit the shining cleavages of feldspar. One dike, No. 11 (Pl. II), from the east side of Pottier's point, near Burlington, consists almost entirely of large feldspar phenocrysts. Quartz phenocrysts are much rarer, although noted in two dikes. Without recourse to the microscope little could be added to the above macroscopic description.

Under the microscope these rocks are at once seen to have a marked and characteristic trachytic structure—that is, the groundmass consists of small feldspar laths, not infrequently in fluidal arrangement.[2]

[1] M. Hunter and H. Rosenbusch: Ueber Monchiquit, ein Camptonitisches Ganggestein aus der Gefolgschaft der Eleolith-Syenite. Tschermak's Min. u. Petrog. Mitth., Vol. XI, 1890, p. 445. The bostonite is incidentally mentioned evidently as a "caveat." The name applies so well to the dikes discussed here that we are glad to adopt it.

[2] Rosenbusch-Massige Gesteine, Vol. II, p. 595.

Between the rods one can sometimes detect small masses of interstitial quartz. The groundmass is invariably holocrystalline, and the feldspars are idiomorphic. The quartz is not. The phenocrysts attain a dimension of 3–5$^{mm}$ in most of the slides, but they may occasionally be a little larger. Although generally kaolinized, it can be readily seen that they are but once twinned, and are doubtless in the great majority of cases orthoclase. The small rods are also once twinned, and, as shown by the analyses later given, they appear to be both orthoclase and anorthoclase. A few well-authenticated plagioclases are recognizable. At least some of the interstitial quartz may be secondary, perhaps all. When alteration has made the feldspars of the groundmass muddy or kaolinized, they assume a sort of elliptical outline under the microscope, and look like so many cross sections of grains of wheat lying together.

It is a remarkable fact that in no case has any recognizable dark silicate been found in a slide. Spots of limonite and iron stains are indeed seen in some, and these may have once been bisilicates, but it is very doubtful, for none appear in the freshest slides. Nor is any magnetite to be noted. A few stray crystals or irregular masses of pyrite are seen, but they are probably infiltrations. The dikes are singularly free from any basic minerals whatever and present a very pure crystallized feldspathic magma.

The structure is shown in the accompanying reproductions of microphotographs. Fig. 1, from dike 566 (Pl. II), exhibits a phenocryst with the somewhat fluidal arrangement of the smaller rods around it.

In alteration the dikes afford nests of calcite and quartz, while the usual muddy kaolin is abundantly present. The calcium for the formation of calcite is probably derived in large part from the infiltrating limy waters of the neighboring slates, throughout which veins of calcite are extremely common. The analyses of fresh dike rock in general show little calcium.

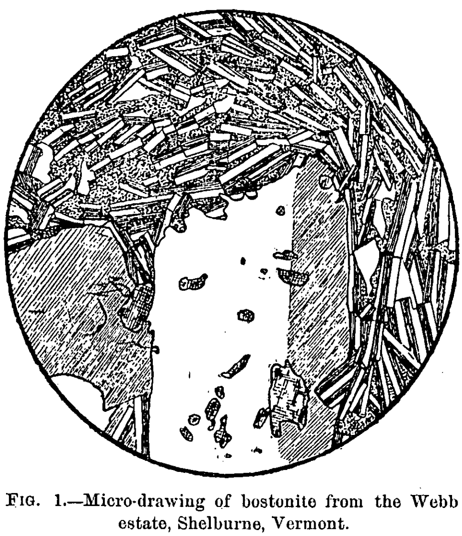


FIG. 1.—Micro-drawing of bostonite from the Webb estate, Shelburne, Vermont.

The chemical composition is shown by the following analyses. No. 566 appears but little altered in thin section, although the loss shows that some changes have occurred. It may be taken as a fair representative of the average dike. No. 11 is more advanced in alteration, and is also quite different in composition. Lime is much more abundant, the alkalies recede and the silica is much less. This dike consists of large feldspar phenocrysts, which in the slide are contained in a finely crystalline groundmass. They are not very fresh. The analysis indicates a soda-lime feldspar, as well as orthoclase, and marks a passage toward an andesitic type or a porphyrite. The percentage of iron oxide, 3·92, is chiefly due to disseminated scales of hematite, which give the base a reddish tint.[1] The analysis of No. 102 was made thirty years ago by Dr. G. F. Barker for President E. Hitchcock and is from the second volume of the Vermont Reports, p. 585. The material was derived from the groundmass of the breccia-porphyry of Nash's point. It is more acidic than the other analyses, but shows a percentage in alkalies resembling No. 11 in their ratio to each other. (Pl. II.)

| | No. 566. Kemp, $\frac{2}{2}$. | No. 11. Morrison, $\frac{2}{2}$. | No. 102. Barker. |
|---|---|---|---|
| Loss | 2·33 | 6·57 | 1·70 |
| $SiO_2$ | 62·28 | 53·40 | 67·30 |
| $Al_2O_3$ | 19·17 | 20·82 | } 19·10 |
| $Fe_2O_3$ | 3·39 | 3·92 | |
| CaO | 1·44 | 7·05 | 0·79 |
| MgO | trace. | 1·53 | trace. |
| $K_2O$ | 5·926 | 2·97 | 4·74 |
| $Na_2O$ | 5·374 | 3·79 | 6·04 |
| Total | 99·910 | 100·05 | 99·67 |
| Spec. grav | 2·648 | ........... | ........... |

The great amount of soda in No. 566 is very suggestive. As no well-marked plagioclase appears in the slide, which indicates a very homogeneous rock, the inference is strong that some soda orthoclase (anorthoclase) is present and that the dike is allied to the pantellerites and keratophyres. A series of analyses are appended, which bring this out the more strongly. Nos. I, II and III are analyses of feldspars separated from rocks of related character from various Canadian localities in the region of Montreal. No. IV is of the groundmass of such a rock after it had been treated with dilute nitric acid, a procedure that would tend to increase the acidity. They were all made by T. S. Hunt from 1853 to 1856. The striking similarity which they bear to the analyses of feldspars from the trachytic rocks of the island of Pantelleria, Nos. V and VI, by Förstner can not but arrest attention. Förstner was able to isolate and examine his crystals both optically and with the goniometer, and on these determinations established anorthoclase as a separate species, but so far as the chemical identity of this mineral is concerned it is well brought out by Hunt's analyses, and the interest is the greater because Hunt's material came from rocks called by him trachytes. He speaks of the feldspar as orthoclase, and doubtless consid-

[1] The analysis of No. 11 was kindly made by Mr. W. H. Morrison, resident graduate in chemistry at Cornell University.

ered the soda as replacing the potash, much as sanidine is usually thought to contain considerable soda. Analysis VII, by T. M. Chatard, is of the phenocrysts of the keratophyre from Marblehead Neck described by J. H. Sears. The keratophyre described by W. S. Bayley[1] from Pigeon Point, Minn., is much more acidic.

| | I. | II. | III. | IV. | V. | VI. | VII. |
|---|---|---|---|---|---|---|---|
| $SiO_2$ | 65·70 | 65·15 | 66·15 | 67·60 | 66·06 | 66·03 | 65·66 |
| $Al_2O_3$ | 20·80 | 20·55 | 19·75 | 18·30 | 19·24 | 19·37 | 20·05 |
| FeO | ........ | ........ | ........ | ........ | 0·54 | ........ | trace. |
| $Fe_2O_3$ | ........ | ........ | ........ | 1·40 | ........ | 1·53 | trace. |
| MnO | ........ | ........ | ........ | ........ | ........ | ........ | 0·13 |
| CaO | 0·84 | 0·73 | 0·95 | 0·45 | 1·11 | 0·73 | 0·67 |
| MgO | ........ | ........ | ........ | ........ | 0·11 | 0·02 | 0·18 |
| $K_2O$ | 6·43 | 6·39 | 7·53 | 5·10 | 5·45 | 5·40 | 6·98 |
| $Na_2O$ | 6·52 | 6·67 | 5·19 | 5·85 | 7·63 | 7·57 | 6·56 |
| Loss | 0·50 | 0·50 | 0·55 | 0·25 | none. | none. | 0·41 |
| | 100·79 | 99·99 | 100·12 | 98·95 | 100.14 | 100·65 | 100·64 |

I. T. S. Hunt: Feldspar from Brome (Canada) Trachyte, Amer. Jour. Sci., Ser. ii, vol. XXXVIII, p. 97; geology of Canada, 1853–56.

II. T. S. Hunt: Feldspar from Shefford (Canada), op. cit., p. 97. F. D. Adams has described microscopically a rock from Shefford as a quartz-free porphyry. Geol. of Canada, 1880–'81–'82, p. 10A.

III. T. S. Hunt: Feldspar from Chambly (Canada), op. cit., p. 98.

IV. T. S. Hunt: Feldspar Groundmass of Chambly dike after treatment with dilute nitric acid, op. cit., p. 98.

V and VI. H. Förstner: Zeitschrift für Krystallographie, vol. VIII, 125–202, 1883. Neues Jahrbuch, 1884, vol. II, p. 171.

VII. J. H. Sears: On Keratophyre from Marblehead Neck, Bull. Mus. Comp. Zoöl, vol. XVI, No. 9, p. 170. Analysis by T. M. Chatard.

In the further discussion of the basic dikes it will appear that in the close field connection which they show with the bostonite we have an association of rock types not unlike those long known near Montreal[2]; in many respects similar to others at Marblehead, near Boston;[3] and

[1] W. S. Bayley—A quartz keratophyre from Pigeon Point and Irving's augite-syenites. Am. Jour. Sci., Ser. iii, vol. XXXVII, p. 54.

[2] T. S. Hunt: See papers cited under Analyses I–IV above. Also Geol. Survey of Canada, 1863, p. 655. B. J. Harrington, Geol. Survey of Canada, 1877–'78, p. 429. A. Lacroix, sur la syenite elæolithique de Montreal et sur les modifications de contact endomorphes, et exomorphes de cette Roche, Compte Rendu, June 2, 1890, p. 1152. Also Descriptions des syenites nepheliniques de Ponzac, Hautes Pyrenees, et de Montreal, Canada, et de leurs phenomenes de contact. Bull. Soc. Geol. France, 3 vol. XIII, 1890, No. 7, 511–558. Further contributions are to be expected from Messrs. Harrington and F. D. Adams.

[3] A. Hyatt: Remarks on the Porphyries of Marblehead, Proc. Boston, Soc. of Natural History, vol. XVIII, p. 220, 1876. T. T. Bouvé: The Origin of Porphyry, op. cit., vol. XVIII, p. 217. M. E. Wadsworth: The Trachyte of Marblehead Neck, Mass., op. cit., vol. XXI, p. 288. Also Geology of Marblehead, op. cit., vol. XXI, p. 306. Zircon syenite from Marblehead, Mass., op. cit., vol. XXI, p. 406. W. O. Crosby: Geology of Eastern Mass. Separate volume issued by the Boston Society of Nat. Hist. J. S. Diller: The Felsites and their Associated Rocks north of Boston, Bull. Mus. Comp. Zool., vol. VII, p. 165. J. H. Sears: On Keratophyre from Marblehead Neck, Mass., op. cit., vol. XVI, p. 167.

to the dikes recently brought to notice near Rio Janeiro, Brazil.[1] In all three localities they are associated with eleolite-syenites. Basic dikes without bostonite are almost invariably associated with eleolite-syenite Eleolite-syenite has not yet been discovered nearer to the Lake Champlain igneous centers than Montreal, which is 100 miles north of Burlington. Igneous phenomena are, however, abundant in the interval. It may be that eleolite-syenite will yet appear in the eastern Adirondacks. The Montreal rocks related to bostonites, or identical with them, were called trachytes by Hunt, as were also certain of the exposures described in this paper by the Hitchcocks in the Vermont Report. Wadsworth applied the same name to the Marblehead dikes, while others called them porphyries. F. D. Adams, as noted in the references under Analysis II, described a dike from Shefford, Canada, as a quartz-free porphyry. Beyond question if no special name is given to dike forms of porphyries and trachytes, these names would be best applicable. Inasmuch, however, as in the present instance, the dikes are quite remote from any great parent mass or volcanic center, the term bostonite has been employed to place them definitely with the dike rocks and to emphasize their association in the field with basic dikes. In structure and in composition, so far as our observation goes, they do not essentially differ from trachytes or porphyries any more than these do from each other.[2]

### THE BRECCIA BOSTONITES.

On the east side of Shelburne point and also on the west side a broad dike (20 feet) outcrops (Nos. 7 and 9 of Pl. II), which is doubtless continuous between. It is a most remarkable rock, and consists of angular pieces of slate and red quartzite cemented together by an igneous base. The cementing base is not very fresh in the attainable specimens, but is clearly of the same nature as the groundmass of the bostonites. The included fragments are angular and do not appear to be notably altered by the fact of their inclusion. They preserve sharp edges and polarize like ordinary sedimentary rocks.

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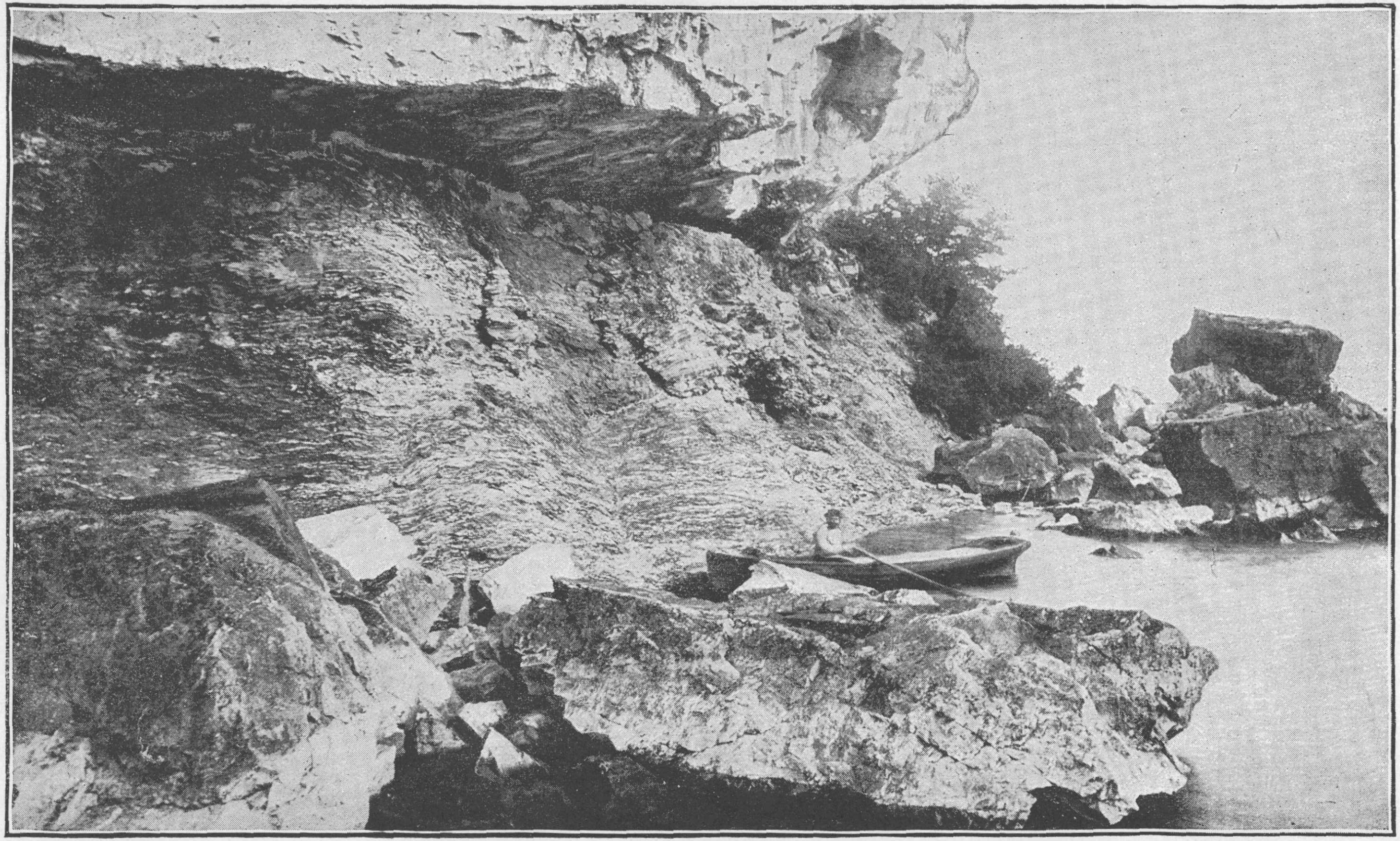
[1] O. A. Derby: On Nepheline Rocks in Brazil, with reference to the association of Phonolite and Foyaite, Quart. Jour. Geol. Soc. London, 1887, p. 457.

Franz Fr. Graeff: Mineralogische-petrographische Untersuchung von Elæolite syeniten von der Serra de Tingua, etc. Neues Jahrbuch, vol. II, 1888, p. 222.

M. Hunter and H. Rosenbusch: Ueber nonchiquit, ein camptonitisches ganggestein aus der gefolgschaft der elæolith syenit. Tschermak's Min. u. Petrog. Mitt. vol. XI, 1890, p. 445.

[2] Since the above was written the senior writer of this paper has received a letter from Prof. Rosenbusch, who, with kindness which is quite characteristic (and of which a deeply felt appreciation may be here expressed), has examined a suite of specimens submitted to him. He fully indorses the determination of the dikes as bostonite. Dikes 11 and 29 (Shelburne point, near Burlington, Pl. II), he says, have a surprising likeness to certain syenite porphyries described by Brögger from the neighborhood of Christiania. Rosenbusch also determines the sharp rhombohedra in dikes 33 and 35 (also from Shelburne point) to be carbonates of magnesium and iron and not calcite, and remarks the resemblance of the two dikes to others near Montreal.



WHITE SANDSTONE (SUPPOSED CAMBRIAN) OVERTHRUST ON UTICA SLATE, LONE ROCK POINT, NEAR BURLINGTON, VERMONT.

Two explanations may be offered of this rock. One that it has been intruded on a line of previous faulting and attrition, which have broken up the walls and have left loose material to be gathered up by the intrusive magma. This explanation has the greater weight with the writers. The other is that it represents only the upper portion of a dike, and thus contains the float material which the advance of an intrusive body that forced its own passage would naturally gather from the walls. The lack of such inclusions in the neighboring dikes may be due to the fact that their tops have been eroded. This breccia dike was first recorded by Zadock Thompson.[1]

A similar dike, but much narrower, is found on Nash's point, and has been described by President Hitchcock.[2] This is likewise a most interesting rock, and, as pointed out by President Hitchcock, consists of a mass of somewhat rounded fragments of Archean norite, red sand-rock (Cambrian), and slate (Hudson river), which are chiefly gathered in the middle portion. They are all cemented together by a bostonite groundmass. Under the microscope sections of the norite show plagioclase and garnet, all exhibiting the results of dynamic action. Sections of the red quartzite have the usual fragmental character, with the evidences of strain less developed. President Hitchcock's hypothesis of its origin is discussed later. His names for the included rocks differ in some respects from those given here, as subsequently set forth. (See Pl. III.)

The inclusions indicate that the dike has come from a source at least beneath or in the norites, and the same inference holds good for the other dikes not provided with inclusions. They also prove that the red quartzite underlies the slates at this point. Inclusions of feldspathic masses, appearing to be from Archean norites, and mentioned above as occurring in the dike at the Willard's ledge quarries, suggest a like deep-seated source for the basic dikes. The parent masses of these narrow bodies are therefore at such a distance below their present outcrop that it comprises the thickness of the slates, of the red quartzite, and of an indefinite amount of norite.

The sheet or bedded dike of porphyry on the end of Nash's point is likewise abundantly provided with inclusions of slate from its immediate walls. They are not noticeably altered.

Brecciated porphyries formed of a broken eruptive rock that has become recemented have been mentioned by Pumpelly from Pilot Knob[3] and by Crosby from eastern Massachusetts,[4] but the phenomena are obviously different from those here described.

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[1] Thompson's Appendix, pp. 52–53, 1853.

[2] E. Hitchcock: On certain Conglomerated and Brecciated Trachytic Dikes in Vermont, etc. Proc. Am. Ass. Adv. Sci., vol. XIV, p. 156. Geol. of Vermont, vol. II, p. 583.

[3] R. Pumpelly: Geol. Survey of Mo. Preliminary Report on the Iron Ores and Coal Fields.

[4] W. O. Crosby: Geology of eastern Mass., p. 50.

### THE BASIC DIKES.

The basic dikes are all compact dark rocks that to ordinary macroscopic examination give almost no indication of their constitution. The only apparent minerals are feldspars in the coarser diabases and in the more basic dikes an occasional glistening hornblende or augite prism. The thin sections exhibit a series of mineralogical mixtures extending from very typical ophitic diabase through camptonites, in which the dark silicates become idiomorphic and the feldspars recede, to aggregates of augite and hornblende lacking feldspar entirely and having comparatively little glass. Olivine is occasionally seen in a fresh condition, but in most dikes an alteration product not always satisfactory alone indicates its probable original presence. The subordinate minerals are noted in the particular description.

The basic dikes are described under the following four types—diabase, including olivine-diabase, camptonite, monchiquite, and fourchite.

### THE DIABASES.

The true diabase dikes are principally if not entirely found in the crystalline Archean areas. They are thus on the west side of the lake and in several cases back in the mountains. Diabase is the characteristic type of rock that forms the dikes which so plentifully intersect the lenses of magnetite.

In the sections the plagioclase exhibits the characteristic lath-shaped, or sometimes rather broader, idiomorphic crystals, abundantly twinned. They have at times a marked radiating arrangement (dike 62, Trembleau point), the "divergent-strahlig" structure of Lossen. The plagioclase has at times a dark core of inclusions which closely follow the rectangular outline of the original crystal. These are doubtless alteration products due to a change that spreads from the core of the crystal outward. Any kaolinized matter in this position would easily become stained by iron oxide filtering in. Minute apatite crystals are also a not infrequent inclusion. The plagioclase was separated by Thoulet's solution from Dike 67, of Trembleau point, near Port Kent. It was found that concentration by panning before the employment of the heavy solutions is extremely advantageous.[1] An almost clean feldspar powder can thus be separated that needs but little further treatment. (Fig. 5.)

| Plagioclase. | Dike 67. I. | Dike 67. II. | Atomic ratios. | |
|---|---|---|---|---|
| Loss | 0·72 | | | |
| $SiO_2$ | 57·82 | 58·38 | ·973 | 11 |
| $Al_2O_3$ | 28·16 | 28·43 | ·276 | 3 |
| CaO | 7·72 | 7·79 | ·139 | $\frac{3}{2}$ |
| $Na_2O$ | 5·352 | 5·46 | ·087 | 1 |
| | 99·772 | | | |

[1] See O. A. Derby: Occurrence of Xenotime as an accessory element in Rocks. Am. Jour. Sci., ser. III, vol. XLI, p. 308. Mr. Derby personally taught us the use of the batea.

From this it appears that the feldspar belongs in the andesite series. Column II is recalculated so as to throw out the loss on ignition.

In allotriomorphic crystals packed in between the feldspar rods, is found the augite. It tends at times to become idiomorphic, and then marks a passage to augitic camptonites. This tendency is very widespread, and indicates the close affinities of the two rocks. The augite varies from a slight pink to greenish, and many crystals possess a very faint pleochroism. In other respects it is common, normal augite. In the heaviest residues obtained by panning crushed material from Dike 67, at Trembleau point, grains of hypersthene were detected, although no trace of this mineral has been seen in any of the thin sections from the dikes. It did not come from any inclusions of neighboring norite, for the material was selected with the greatest care. It is interesting to note in this connection the recent announcement of hypersthene in Triassic diabase, by Campbell and Brown.[1] It is not unlikely that this orthorhombic pyroxene is in many diabases where the chance cut of a section has failed to show it.

Biotite is sometimes seen in the slides, but only as a very subordinate mineral. It forms small scales closely associated with magnetite and more or less as a border around it. The biotite is regarded as an original mineral that followed closely on the ores in period of formation, and not as resulting from the mutual secondary action of magnetite and plagioclase on each other, as is concluded by Wadsworth when treating of similar occurrences in the gabbros of Minnesota.[2]

Of the magnetite nothing of note need be added beyond that it is abundant and in irregular grains.

The process of alteration seems to be the same wherever noted. The bisilicates pass into chlorite or into what in other cases appears to be serpentine. This latter is a yellow or amber-colored mass, not always showing a very marked aggregate character, lacking in pleochroism, and not very strongly refractive. The chlorite is better marked and was identified by its pleochroism. Some dikes are in such an advanced stage of alteration that they present almost nothing of a definite character. Clay or kaolin, calcite, limonite, and indefinite dirt make up the slide. Very little recognizable epidote has been noted.

An interesting and exceptional alteration is afforded by the dike at Palmer hill, near Au Sable Forks. The feldspar has yielded a colorless negative, uniaxial, rather brightly polarizing mineral with abundant rectangular cleavages. This is scapolite. It occurs in scattered masses and often, with quartz, forms nests of secondary character. Scapolite as an alteration product from plagioclase has long been known in connec-

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[1] Campbell and Brown: Composition of certain Mesozoic igneous rocks from Virginia. Bull. Geol. Soc. Amer., 1891, p. 339.

[2] M. E. Wadsworth: Bull. II. Minn. Geol. Surv., p. 65, and Pl. III.

tion with various rocks associated with the apatite deposits of Norway, and more recently has been discovered in the same relations in Canada.[1]

The course through which the alteration has been brought about has been discussed by Judd.[2] It is urged that solutions containing sodium chloride penetrate the plagioclase along "solution planes,"[3] after which dynamic metamorphism in connection with the sodium chloride changes the plagioclase to scapolite. There seems to have been no dynamic metamorphism necessarily developed in the present instance, but doubtless the infiltration of sodium chloride in solution or of hydrochloric acid, which reacted on the sodium in the feldspar, has aided the change. Lacroix has also recently described the alteration to dipyre of the plagioclase in a diabase in the Pyrenees, along the contact with intruded eleolite-syenite.[4]

An analysis of the Palmer hill dike yielded the results given in column I. By its side is placed for comparison No. II, an analysis of a diabase from the vicinity of Boston, described by W. H. Hobbs.[5] No. III is from the region of Keene valley and the analysis is by A. R. Leeds.[6]

| | I. Kemp. | II. | III. |
|---|---|---|---|
| $SiO_2$ | 45·46 | 48·75 | 43·41 |
| $Al_2O_3$ | 19·94 | 17·17 | 19·42 |
| $Fe_2O_3$ | 15·36 | 0·41 | 5·72 |
| $FeO$ | .......... | 13·62 | 6·69 |
| $CaO$ | 8·32 | 8·82 | 9·11 |
| $MgO$ | 2·95 | 3·37 | 5·98 |
| $MnO$ | .......... | 0·91 | .......... |
| $K_2O$ | 3·21 | 2·40 | 0·47 |
| $Na_2O$ | 2·12 | 1·63 | 4·39 |
| $TiO_2$ | .......... | 0·99 | 0·35 |
| $P_2O_5$ | .......... | 0·68 | .......... |
| $CO_2$ | .......... | trace | 2·00 |
| $FeS_2$ | .......... | trace | .......... |
| Loss | 2·30 | .......... | 3·00 |
| | 99·66 | 100·17 | 100·54 |
| Sp. gr. | 2·945 | 2·985 | |

[1] F. D. Adams and A. C. Lawson: On some Canadian rocks containing scapolite, etc. Canadian Record of Science, 1888, p. 185. The paper gives a general review of the literature of scapolite in these relations and many citations of authorities.

[2] J. W. Judd: On the processes by which a plagioclase feldspar is converted into scapolite. Mineralogical Magazine, vol. VIII, p. 186.

[3] For the description of solution planes, see papers by J. W. Judd, in the Quar. Jour. Geol. Soc., vol. XLI, 1885, p. 383; vol. XLII, 1886 p. 82. Mineralogical Magazine, vol. VII, 1886., p. 81.

[4] Lacroix: Sur les phénomènes de contact de la syénite elæolithique de Pouzac. Compte Rendu, No. 110, p. 1011, 1890.

[5] W. H. Hobbs: On the petrographical characters of a dike of diabase in the Boston basin. Bull. Mus. Comp. Zool., vol. XVI, p. 1.

[6] A. R. Leeds: Notes on the lithology of the Adirondacks. Thirtieth Ann. Rep. N. Y. State Museum, p. 102.

In I all the iron was estimated as $Fe_2O_3$. The excess of potash over soda in the first two of these dikes is exceptional for diabase. While the rather abundant biotite in No. I in part accounts for it, the mica seems hardly sufficient to afford it all. Probably the augite contains some, for it is unlikely that the feldspar of so basic a rock has much. The dike contains also less $SiO_2$ than our most typical and best known American diabases, those of the eastern Triassic areas, for these afford with monotonous uniformity from 51 to 53 per cent.

The question may be raised here as to the causes that lead in some instances to the formation of the ophitic structure of true diabase and in others to the approximately panidiomorphic structure of camptonite, in dikes of the same general width and in adjacent localities. The curious exception that the diabases offer, of feldspars crystallizing before the dark silicates, has been suggested by Rosenbusch[1] as due to the excess of RO bases over the $R_2O$. This same relation holds good, however, in the camptonites, as is shown by the analyses which follow, but in them the structure is markedly idiomorphic.

It is notable that in the dikes of the Lake Champlain region the diabases are in the areas of crystalline rocks of Archean age, while the camptonites are in the later stratified rocks.[2] This would necessitate the passage of the fused magma of the latter through a much greater thickness of rock before it reached the surface or at least before it solidified; while the diabase has chilled nearer its parent mass. It may be that the wall rock has exerted some influence; certainly the camptonites must have remained longer molten. We are rather led by the varying analyses to ascribe the different structures to physical causes like these than to peculiarities of chemical composition.

The contact phenomena of the diabases are described and figured later in the particular mention of Trembleau point, p. 45, where they are best seen.

Olivine appears in a few dikes and what may be an alteration product of it in certain others. While, strictly speaking, such dikes should be called olivine-diabase, they do not seem to differ from the normal diabase in much else than in the presence of chrysolite.

Diabase (including olivine-diabase) is an extremely common dike-rock in the Archean rocks of Canada and the northern United States. While the dikes are often recorded simply as trap, it is probable that they belong in the majority of cases to this group. A citation of those which have been microscopically determined, so far as known to us, is here appended. We desire to acknowledge the gift of chips for comparison from Messrs. Tight, Haworth, C. W. Hall, and Hobbs, writers of papers mentioned below:

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[1] H. Rosenbusch: Ueber das Wesen der körnigen und porphyrischen Structur bei massigen Gesteinen. Neues Jahrbuch, vol. II, 1882, p. 1.

[2] This relation is not true of camptonites elsewhere. The original exposures at Livermore falls on the Pemigewassett river are in mica schist; the dikes at Fort Montgomery and Forest of Dean, Orange county, N. Y., are in gneiss.

CANADA.

W. S. BAYLEY. Notes on the microscopic examination of rocks from the Thunder bay silver district. Geol. Surv. of Canada, 1887, p. 1154.

ROBERT BELL. Observations on the Labrador coast, Hudson straits and bay. Geol. Surv. of Can., 1882–'83–'84, pp. 14–15.

H. W. FAIRBANKS. Notes on the characters of the eruptive rocks of the Lake Huron region. Amer. Geologist, vol. VI, p. 162.

B. J. HARRINGTON. Notes on a few dikes cutting Laurentian rocks, more especially with reference to their microscopic structure. Canadian Naturalist, vol. VIII, No. 6, p. 315.

HERRICK, TIGHT and JONES. Dikes at Michipicoton bay, Lake Superior. Bulletin Denison University, vol. II, p. 119.

A. C. LAWSON. Diabase dikes of the Rainy lake region. Proc. Canadian Institute, ser. iii, vol. V, 1888, p. 178. Amer. Geol., vol. I, p. 199.

A. C. LAWSON and F. T. SCHUTT. Petrographical differentiation of certain dikes of the Rainy lake region. Proc. Am. Ass. Adv. Sci., vol. XXXVIII, 1889, p. 246.

M. E. WADSWORTH. Dikes at Notre Dame bay and the Betts cove copper mines. Amer. Jour. Sci., ser. iii, vol. XXVIII, p. 94.

M. E. WADSWORTH. Mentions diabase dikes near Bathurst, N. B., in a paper on Ore deposits. Boston Soc. Nat. Hist., 1884, p. 207.

INDIAN TERRITORY.

R. T. HILL. Reconnaissance of the Ouachita mountain system in Indian Territory. Determinations of diabase by J. F. Kemp. Am. Jour. Sci., ser. iii, vol. XLII, p. 118.

MAINE.

W. O. CROSBY. Geology of Frenchman's bay, Me. Proc. Boston Soc. Nat. Hist., 1880, 109. Amer. Jour. Sci., ser. iii, vol. XXIII, p. 64.

Q. E. DICKERMAN and M. E. WADSWORTH. An Olivine-bearing diabase from St. George, Me. Boston Soc. Nat. Hist., vol. XXIII, p. 28.

J. F. KEMP. Trap dikes near Kennebunkport, Me. Amer. Geol., vol. V, p. 129, March, 1890.

G. P. MERRILL. Olivine diabase from Addison's point. Tenth Census, vol. X, p. 24.

The mention of dikes which have not been microscopically determined is very frequent in papers dealing with the geology of Maine. Many of these are doubtless diabase.

MASSACHUSETTS.

W. O. CROSBY. Geology of eastern Massachusetts.

B. K. EMERSON. The Deerfield dike and its minerals. Amer. Jour. Sci., ser. iii, vol. XXIV, pp. 195–270, 349.

W. H. HOBBS. On the petrographical characters of a dike of diabase in the Boston basin. Bull. Mus. Comp. Zool., vol. XVI, No. 1.

A. C. LANE. Geology of Nahant, Mass. Boston Soc. Nat. Hist., vol. XXIV, p. 91. Mentions 500 dikes.

N. S. SHALER. Geology of Cape Ann. Ninth Ann. Rep. Director U. S. Geol. Surv., p. 608. Three hundred and fifty dikes of diabase and quartz porphyry in a limited area.

MICHIGAN.

WICHMANN. Diabase dike at the Washington mine. Geol. of Wis., vol. III, p. 625.

MINNESOTA.

WADSWORTH, M. E. Bull. No. 2, Minn. Geol. Survey. Peridotytes, Gabbros, Diabases, and Andesites of Minnesota.

MISSOURI.

E. HAWORTH. A contribution to the Archean geology of Missouri. Amer. Geol., vol. I, pp. 280–363.

NEW HAMPSHIRE.

G. W. HAWES. Said to occur in all parts of New Hampshire. N. H. Geol. Survey, vol. III, part 4, p. 149.

NEW JERSEY.

B. K. EMERSON. On a great dike of mica-diabase at Franklin Furnace, N. J. Amer. Jour. Sci., ser. iii, vol. XXIII, p. 376, 1882. This dike is more closely related to the camptonites, a group created since the paper was written.

Diabase dikes are not few in the iron region of New Jersey, as shown by unpublished material in the possession of the senior author of this paper.—J. F. KEMP.

NEW YORK.

LEEDS, A. R., and JULIEN, A. A. In 30th Ann. Rep. N. Y. State Museum, pp. 102, 106, a dolerite dike is mentioned and analyzed.

PENNSYLVANIA.

P. FRASER. Report CCC, 2d Penn. Geol. Surv., p. 138.

H. CARVILL LEWIS. A great trap dike across southeastern Pennsylvania. Amer. Phil. Soc., May 15, 1885, p. 438.

SOUTH CAROLINA.

G. F. RICHARDS. Some microscopic determinations in Bull. Denison Univ., vol. IV, p. 5.

VIRGINIA.

N. H. DARTON and J. S. DILLER. Occurrence of basalt dikes in the upper Paleozoic of Appalachian Virginia. Amer. Jour. Sci., ser. iii, vol. XXXIX, p. 269.

WISCONSIN.

R. D. IRVING and C. R. VAN HISE. One determined from Mosinee. Geol. Wis., vol. IV, p. 651.

## THE CAMPTONITES.

Camptonite, as a name for a particular group of rocks, was introduced by Rosenbusch[1] in the second edition of his invaluable work to indicate those dike rocks which consist of augite, hornblende, and plagioclase, the bisilicates being the most prominent components. They are characterized either by panidiomorphic or a holocrystalline porphyritic structure. The name is based on the first good determination of such

[1] H. Rosenbusch: Physiographie der mässigen Gesteine, vol. I, 1886, p. 333.

rocks by Hawes,[1] from the town of Campton, in the Pemigewassett valley, New Hampshire. Hawes called the rocks which there occur in several neighboring and parallel dikes, diorite, diabase, and olivine-diabase. In the further description of the camptonites of this paper, it will be seen that mineralogical mixtures corresponding to the names of Hawes are what characterize these basic rocks in the Lake Champlain region. The grouping of Rosenbusch was felicitous, and has been found useful by subsequent observers, as it enables an accurate and intelligent classification to be made. It has been advocated by one of us[2] that the hornblende should be the principal diagnostic mineral of a camptonite. Dikes consisting essentially of augite and plagioclase commonly approximate the ophitic structure of diabase so closely that it has not seemed advisable to give them a separate name from diabase. Transitions are indeed known to a marked panidiomorphic structure,[3] and augite-plagioclase dikes occur among those here described which differ only in this way from effusive diabase, yet the greater number, if not all of them, have some basaltic hornblende, and are here designated augite-camptonite. The term camptonite alone is used in this paper to indicate the rocks in which hornblende predominates.

The camptonites consist of brown basaltic hornblende, augite, plagioclase, magnetite, and occasionally a little intermingled glassy matter. In those considered typical, there is no augite whatever. This is the case in two dikes, so far as the slides indicate. Usually, however, augite is also present, and may even predominate, marking thus a transition toward diabase. The minerals are markedly panidiomorphic, and the large hornblendes and augites give at times a porphyritic character.

The hornblende is the most conspicuous and attractive component. It exhibits, at times, large phenocrysts of the first generation, $3^{mm}$ in maximum diameter, prismatic and bounded by $\infty P$ (110) and $P \infty'$ (010). It has strong pleochroism, brown to yellow. In marked distinction to the augite, it shows no zonal structure whatever.

The second generation of hornblende is in small acicular crystals $0 \cdot 1^{mm}$ wide by $0 \cdot 3$–$0 \cdot 5^{mm}$ long, and in other respects is only a miniature reproduction of the first generation. These small crystals occur in all the dikes of the camptonite group and are, as will be noted later, very generally present in the monchiquites, although it may be in small amount.

The augite is likewise in two generations. The older forms prismatic crystals, usually zonal, and having darker green cores surrounded by

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[1] G. W. Hawes: On a group of dissimilar eruptive rocks at Campton, N. H., Amer. Jour. Sci., ser. III, vol. XVII, p. 14.

[2] J. F. Kemp: Trap dikes near Kennebunkport, Me., Amer. Geol., vol. V, p. 137.

[3] Compare W. C. Brögger, Zeitschrift für Kryst., vol. XVI, 1890, p. 23, where camptonite dikes are recorded as apophysae of a laccolite of diabase; also the paper on Kennebunkport dikes, just cited, which describes a close association of camptonite and diabase.

lighter, almost colorless rims. These two portions may differ 10° in extinction. The crystals reach as high as 5mm in diameter. The second generation is very small, in acicular prisms well nigh colorless.

The plagioclase is less perfectly developed than the bisilicates. It inclines, however, to the lath-shaped form and is invariably twinned. In the camptonites the sharp idiomorphic character of the crystals, as seen in diabase, somewhat recedes.

The relations of the several minerals and the undifferentiated base is shown in Fig. 2.

As illustrative of the chemical composition of the camptonites the following two analyses, I and II, are quoted from a previous paper by the writers, and to these is added a series of analyses of the same species of rock from other districts.

FIG. 2.—Micro-drawing of camptonite from Dorset Mountain, Vermont.

| | I. | II. | III. | IV. | V. | VI. |
|---|---|---|---|---|---|---|
| $SiO_2$ | 43·50 | 41·00 | 41·94 | 40·95 | 48·19 | 44·87 |
| $Al^2O_3$ | 17·02 | 21·36 | 15·36 | 16·45 | 16·79 | 17·28 |
| $Fe_2O_3$ | 13·68 | 13·44 | 3·27 | 13·47 | 18·37 | 11·04 |
| FeO | .......... | .......... | 9·89 | .......... | .......... | .......... |
| MnO | .......... | .......... | 0·25 | 0·33 | .......... | trace |
| $TiO_2$ | .......... | .......... | 4·15 | 3·39 | .......... | 6·74 |
| CaO | 8·15 | 10·40 | 9·47 | 10·53 | 6·85 | 7·54 |
| MgO | 6·84 | 3·85 | 5·01 | 6·10 | 1·32 | 4·95 |
| $K_2O$ | 3·02 | 1·31 | 0·19 | 1·28 | 1·11 | 2·62 |
| $Na_2O$ | 2·84 | 2·86 | 5·15 | 4·00 | 5·59 | 1·61 |
| $P_2O_5$ | .......... | .......... | .......... | 0·29 | .......... | 0·45 |
| $CO_2$ | .......... | .......... | 2·47 | .......... | .......... | .......... |
| Loss | 4·35 | 5·00 | 3·29 | 3·84 | 2·31 | 2·49 |
| | 99·40 | 99·22 | 100·44 | 100·63 | 100·53 | 99·59 |

I. Fairhaven, Vt.
II. Proctor, Vt., by J. F. Kemp, from Kemp and Marsters, Camptonite dikes near Whitehall, Washington county, N. Y., Amer. Geol., August, 1889, p. 97.
III. G. W. Hawes, Campton Falls, N. H., Amer. Jour. Sci. ser. iii., vol. XVII, p. 14.
IV. B. J. Harrington, Montreal, Geol. Survey of Canada, 1877–78, p. 439.
V. J. F. Kemp, Orange county, N. Y., Amer. Jour. Sci., April, 1888, p. 331.
VI. L. M. Dennis (see J. F. Kemp), Dikes of Hudson river highlands, Amer. Naturalist, August 1888, p. 694.

The analyses show a considerable variation in composition, but they all are under 50 per cent $SiO_2$, and no rock properly referable to this group is likely to go over this limit.

The most accessible augite-camptonite is the south dike at the quarries in the Willard's ledge, Burlington. A pure hornblende-camptonite or camptonite proper is the large dike (No. 74) 20 feet wide and less than a mile above Wing's point (see Pl. IV). Several camptonite dikes occur with abundant olivine. They need no detailed description additional to that given of those lacking ths mineral. The olivine is usually much altered and remains only as serpentine.

As already set forth, G. W. Hawes described the first camptonites. In 1878 B. J. Harrington published an account of other identical rocks, from near Montreal, giving the analysis IV quoted above. They were next brought to light by J. F. Kemp, from Orange county, New York, in 1888,[1] and by the present writers as quoted under the table of analyses I and II, from southern Vermont in 1889. About the same time F. L. Nason[2] mentioned another occurrence 30 miles east of the Fairhaven and Proctor dikes of Kemp and Marsters. In 1889 J. F. Kemp[3] likewise reported one from Kennebunkport, Maine, in close association with diabase.

They seem as yet to be less frequent abroad. Erwin Goller[4] has described a number which belong to a series of dikes in the Black Forest. They are very like many American camptonites, although the brown hornblende is much more generally changed to green. Rosenbusch mentions one from the southern Tyrol, described first by Doelter[5] and later by Cathrein.[6] Brögger[7] has recorded them as apophysæ of a laccolite of diabase in the region of Norway so carefully worked out by him. They furnish an association with diabase of great interest as compared with the dikes at Kennebunkport, Maine.

## MONCHIQUITES.

The name Monchiquite has been lately introduced by Rosenbusch[8] to include a group of dike rocks, consisting of olivine, augite, hornblende, biotite (one or all three of the last named), and a glassy base. It was coined from the Monchique mountains in Portugal, where such dikes were discovered in 1850 by Bonet[9] and called basalt and mela-

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[1] J. F. Kemp: Diorite Dike from the Forest of Dean, Orange county, New York, Amer. Jour. Sci., ser. III, vol. XXXV, p. 331. Dikes of the Hudson River Highlands, Amer. Naturalist, August, 1888, p. 691.

[2] F. L. Nason: On a new locality for the camptonite of Hawes and Rosenbusch, Amer. Jour. Sci., ser. III, vol. XXXVIII, p. 229, 1889.

[3] J. F. Kemp: Trap Dikes near Kennebunkport, Maine, Amer. Geol., Mar., 1889, p. 137.

[4] E. Goller: Die Lamprophyrgänge des südlichen Vorspessart. Neues Jahrbuch, vol. VI, Beil. Band, 1888, p. 485. Through the courtesy of Prof. H. Bücking, of the University of Strasburg, we have had a suite of these rocks for comparison.

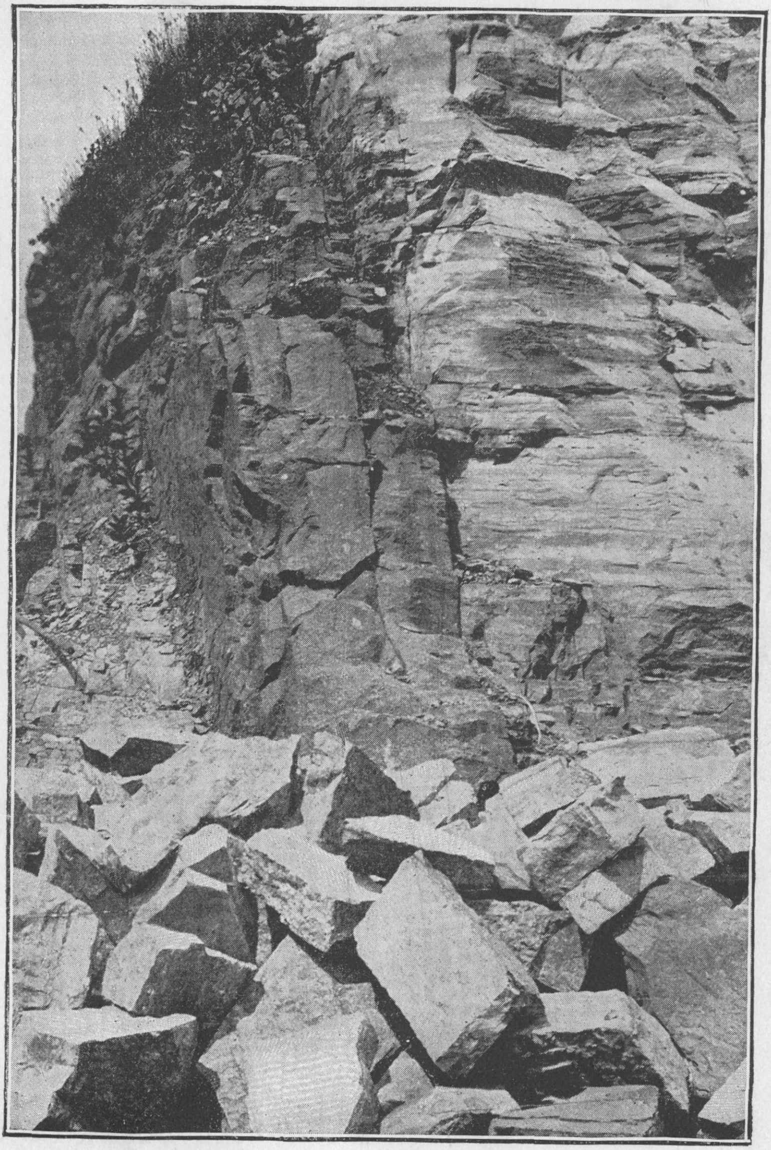
[5] C. Doelter: Tscher. Min. und Petrog. Mitth., 1875, pp. 179, 188, and 304.

[6] A. Cathrein: Zeitschr. f. Krystal., vol. X, 1884, p. 221.

[7] W. C. Brögger: Zeitschr., f. Krystal., vol. XVI, 1890, p. 23.

[8] M. Hunter and H. Rosenbusch: Ueber Monchiquit, ein Camptonitisches Ganggestein aus der Gefolgschaft der Elaeolith-Syenite. Tschermaks Min. und Petrog. Mitth., vol. XI, 1890, p. 445.

[9] Bonet, Algarve. Description géographique et géologique de cette province, Lisbon, 1850.



DIKE OF AUGITE-CAMFTONITE IN CAMBRIAN QUARTZITE AT THE WILLARD'S LEDGE QUARRIES, BURLINGTON, VERMONT.

phyre. Specimens were subsequently collected by Reiss, which years afterwards (1879) came into the possession of Leopold van Werweke,[1] who determined them as limburgite of an abnormal type. Another dike from the neighborhood was later called nepheline-basalt.[2] The monchiquite group was, however, immediately based on studies of Brazilian dikes. These have been brought to light by O. A. Derby[3] in the region about Rio Janeiro, where they are again associated with eleolite-syenite. The material worked up by Hunter and Rosenbusch was sent them by Derby. The alnoite of Törnebohm[4] from the island of Alno, off the coast of Norway, is a related melilite rock, and the dikes from the region of Magnet cove, Arkansas, are of near kinship, as will be subsequently indicated.

In the further development of the Lake Champlain dikes, toward the extreme basic end of the series, there are a number consisting chiefly of zonal augite, small, brown hornblende and biotite crystals, and olivine in an unresolvable base that is only very feebly refractive if not glassy. Magnetite is the only additional mineral.

As in the camptonites, the augite is in two generations, of which the older and larger is precisely like the phenocrysts cited in the description of those rocks. The smaller light green crystals of the second generation are often extremely abundant and make up almost all the slide. The analysis of such a dike (No. 14, given later, is one) must indicate very nearly the composition of the augite, with the exception that a portion of the iron belongs to the magnetite present.

The hornblende is of the brown basaltic variety, and likewise occurs in two generations. The older and larger is like the hornblende of the camptonites. The small crystals of the second generation sink to extreme minuteness and present the strongest resemblance to biotite. In some minute cases we do not feel sure of the identification as between these two. In the altered portions of the base they seem much more numerous than in the more opaque fresh portions. The alteration gives rise to calcite, in which the prisms stand out with sharp definition. Hornblende increases in a few dikes to such an extent that it replaces the augite and affords a hornblende-monchiquite.

The olivine is almost never fresh, and only exhibits the characteristic green alteration serpentine. This latter is not often very definite or characteristic, and it must be confessed that the determinations are not entirely satisfactory. But the masses of green alteration product

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[1] L. v. Werweke: Beitrag zur Kenntniss der Limburgite. Neues Jahrbuch, 1879, p. 451.

[2] L. v. Werweke: Ueber die Nephelin-Syeniten der Serra de Monichique im südlichen Portugal und die denselben durchsetzenden Gesteine. Neues Jahrbuch, 1880, vol. I, pp. 141–186, especially p. 179.

[3] O. A. Derby: On Nepheline Rocks in Brazil, etc. Quart. Jour. Geol. Soc., London, 1887, p. 457.

[4] Törnebohm, cited from the original Swedish by Rosenbusch. Physiographie der massigen Gesteine, pp. 804 and 809.

are always present, even when the augite and hornblende are uniformly fresh, and there seems no other source for it than olivine. Prof. Rosenbusch has, with great kindness, looked over a number of these dikes, and fully indorses the determination of them as monchiquites, which had been previously made by us.

The glassy base is not abundant, and it shows no definite mineralogical relations. Attempts to gelatinize and stain it were not satisfactory, and it probably does not gelatinize, corresponding thus with the "basis of the first kind" ("Basis erster Art") of Bücking.[1] It shows at times feeble double refraction.

The following analyses illustrate the composition of the monchiquite. Analysis I is of Dike No. 2, near Burlington. Under the microscope the slide is seen to be mostly augite, with a few small biotite crystals, and serpentine. Analysis II is of Dike No. 14 on the end of Shelburne (Pottier's) point. It is of much the same mineralogical composition as Dike No. 2, and shows what chemical differences may exist in rocks which in thin section are substantially alike. Analysis III is of Dike No. 21, Shelburne point. The dike is a hornblende-monchiquite, and has more hornblende than augite. The former is in glistening phenocrysts quite visible to the naked eye. The amount of iron oxide is quite remarkable, but whether this affected in any way the ultimate mineralogical result of the cooling magma is a matter for conjecture. Both this and Dike No. 2 are very low in alkalies. (Pl. II.)

Analyses I and II are by Mr. W. H. Morrison, resident graduate in chemistry at Cornell, and Analysis III by E. M. Chamot, assistant in the Cornell laboratory. To both these gentlemen our acknowledgments are gratefully made. Each analysis was made in duplicate.

| | I. Dike No. 2. | II. Dike No. 14. | III. Dike No. 21. | IV. | V. |
|---|---|---|---|---|---|
| $SiO_2$ | 40·37 | 45·13 | 44·30 | 46·48 | 43·50 |
| $TiO_2$ | .......... | .......... | .......... | ·99 | 2·10 |
| $Al_2O_3$ | 17·86 | 18·06 | 7·92 | 16·16 | 18·06 |
| $Fe_2O_3$ | 14·45 | 11·88 | 25·38 | 6·17 | 7·52 |
| FeO | ·38 | ·32 | not det. | 6·09 | 7·64 |
| CaO | 17·61 | 10·17 | 14·67 | 7·35 | 13·39 |
| MgO | 1·63 | 1·12 | 1·98 | 4·02 | 3·47 |
| $K_2O$ | ·83 | 6·06 | .......... | 3·08 | 1·30 |
| $Na_2O$ | 1·29 | 3·57 | .......... | 5·85 | 2·00 |
| Loss | 4·47 | 3·04 | 4·35 | 4·72 | 1·22 |
| | 99·39 | 99·35 | 98·60 | 100·91 | 100·20 |

II. Also contained $P_2O_5$ 0.39.
IV. Monchiquite from Brazil. Hunter & Rosenbusch. Tscher., Mitt., XI, 454. Hunter, analyst.
V. Amphibole monchiquite, Magnet Cove, Arkansas. Ark. Geol. Survey. 1890. Vol. II, p. 295. W. A. Noyes, analyst.

[1] H. Bücking: Basaltische Gesteine aus der Gegend südwestlich von Thüringer Wald und aus der Rhön. Jahrb. d. k. preussischen geolog. Landesanstalt für 1880 und 1881. Through the kindness of Prof. Bücking we have had a suite of specimens for comparison.

The analyses show that the dikes are extremely basic, and may sink very low in alkalies or be quite rich in them. In other respects they vary widely, except in magnesia. The small amount of this element would indicate that olivine is not very abundant. Prof. Rosenbusch writes of dikes 14 and 21 (also 13, 25, and 64) that they are "echte Monchiquite von typischem Habitus". Very much the same range is shown in the analyses as in those of the previous set of camptonites, but no reason appears from the composition why we find in one case camptonite and in another near by monchiquite. Probably more rapid cooling brought it about.

In alteration abundant calcite is formed, and when the base passes into this, as already remarked, the small dark silicates appear with greater definition. Little else of alteration has been remarked, for the dikes are quite fresh, even on exposed portions.

The distribution of monchiquites, the world over, has been already outlined. The creation of this special division of dikes is as yet so recent that the catalogue is not extended. Undoubtedly they will be reported also from the province of Quebec, especially in the Montreal region.

### THE FOURCHITES.

The name fourchite has been introduced by J. F. Williams[1] to describe certain dikes that pierce the eleolite-syenites and related rocks of the exposures near Little Rock and Magnet cove, Arkansas. Fourche mountain near Little Rock is abundantly intersected by them and suggested the name. The dikes differ from monchiquite in lacking olivine as an essential constituent. This mineral is absent or extremely subordinate. Augite is principally present, and with it at times considerable hornblende. In the region about Magnet cove, and at various outlying points, other dikes occur outside the syenite which have biotite as their chief constituent, with more or less augite, rarely hornblende, in a glassy base. These have been called by J. F. Kemp[2] ouachitites, from the Ouachita (pronounced Wáw-shee-taw) river, along which they are especially abundant.

One dike of fourchite is found in the Lake Champlain district, but ouachitites are lacking. In fact, in all but the diabase and a few monchiquites, in which it plays an insignificant part, biotite is lacking. In the norite of Boquet mountain, which lies some three miles east of the town of Essex, New York, was found a narrow dike consisting entirely, so far as revealed by the slides, of idiomorphic brown basaltic hornblende in two generations thickly set in a feebly refracting base, which is not plagioclase. The older and larger hornblende crystals are $0 \cdot 25^{mm}$, the younger and smaller ones $0 \cdot 01 - 0 \cdot 05^{mm}$ in diameter. Magnetite is also present. The rock belongs to the hornblende-fourchites of J.

[1] Williams, J. Francis: Geol. Survey of Ark. Ann. Rep. 1890, Vol II, p. 107.

[2] Kemp, J. F.: Geol. Survey of Ark. Ann. Rep., Vol. II, p. 392.

F. Williams. It must be admitted, however, that if the green alteration product in many of the monchiquites be doubtful as coming from original olivine, the rocks would be fourchites, and, indeed, the slides are very like the Arkansas type. We are indebted to Dr. J. F. Williams for the loan of his best slides. It should also be stated that the base is not always, and in fact seldom, a true glass, but contains many colorless, minute acicular crystals of parallel extinction. These are probably nepheline. The mineral matter containing them shows frequently a feeble refraction, and so, although in other respects resembling glass, it is not perfectly isotropic. In the typical Arkansas fourchites J. F. Williams seldom found a true glass, and he even found some plagioclase that he regarded as secondary.

## ON THE WIDESPREAD ASSOCIATION OF SIMILAR BASIC DIKES WITH ELEOLITE-SYENITE.

The fact that camptonite, monchiquite, and fourchite dikes are almost invariably associated in other localities with eleolite-syenite has been often referred to in the preceding pages. It is our belief that their presence in the Lake Champlain valley indicates that eleolite-syenite is somewhere in the region. There is a vast area in the Adirondacks not yet subjected to petrographic or, indeed, geologic examination of a detailed character. It would not be surprising if such rocks should be identified in the future. Near Montreal eleolite-syenite does occur and is associated with rocks such as we have described, although the Canadian descriptions, as yet published, are meager. It is within the bounds of reason that the Lake Champlain dikes are the extreme southern manifestation of the eruptive action chiefly shown across the national boundary forty to one hundred miles from their principal outcrop. Although this distance seems great, it has a parallel in Arkansas, where dikes of related character to the fourchites are found forty to eighty-five miles from the syenitic centers[1] and are doubtless extreme manifestations of their eruptive action. The Montreal syenite and related rocks are shown to have been intruded after the Trenton Period, whose limestones they cut, and before the Lower Helderberg, to whose conglomerate they have furnished rolled bowlders.[2] This would place them at the close of the Lower Silurian or in the early part of the Upper Silurian. It will at once occur to one familiar with the Green mountains that they were elevated at the close of the Lower Silurian and were formed in one of the great upheavals of New England. We think it probable that the intrusion of the dikes was occasioned by this great disturbance. Outpourings or intrusions of igneous rock almost always attend mountain-making action, and it is reasonable to

[1] J. F. Kemp: On the basic dikes occurring outside the syenite areas of the Magnet Cove Region. Geol. Surv. Ark., vol. II, 1890, p. 392.

[2] Compare A. Lacroix: Sur la syénite éléolithique de Montréal, Canada, etc. Compte Rendu, June 2, 1890, p. 1152, and Bull. Societé Géologique de France, Troisième Série, tome XVIII, p. 523.

suppose that the Green mountains have been no exception. Aside from this line of inference we have no direct evidence of the age of the dikes except that they followed the Utica slate or shale, for this is the latest formation pierced by them. (Pl. III.)

In the tabular statement of them it will be seen at once that they are almost all vertical where found in the sedimentary rocks. Dikes which have suffered no subsequent movements would naturally take this course in coming to the surface. It is reasonable to conclude that the uniform verticality indicates that the wall rocks have not been much, if at all, disturbed since their intrusion, or else that they and their walls have moved en masse over a great territorial extent.

## BRIEF REVIEW OF THE CLASSIFICATION OF THE BASIC DIKE ROCKS.

The institution of the dike rocks as a separate group coordinate with the plutonic or intrusive (*Tiefengesteine*) and the volcanic or effusive (*Ergussgesteine*) rocks had its inception with Rosenbusch.[1] It places the igneous rocks which have cooled in relatively narrow fissures by themselves and contrasts them on the one hand with those cooling, in masses of great size, slowly and under pressure, and on the other with those cooling likewise in large masses, but with greater celerity and less pressure; in other words, with those below the surface and with those on the surface. In the nature of things we can not conceive of a small body of igneous rock which fills a fissure a few feet wide as originating alone by itself. Igneous phenomena do not manifest themselves in this isolated way. We might perhaps conceive of rock far below the surface and held under such pressure that its temperature while yet solid would be above its normal fusing point at the surface. The formation of a fissure by some movement might relieve the pressure and lower the fusing point along its line so that the adjacent rock would melt and fill it, but where isolated dikes occur, cutting altered or quite unaltered sedimentary beds (as in the region just described), such a supposition is out of the question, and even in plutonic or metamorphic walls it is questionable. The only alternative, then, is to consider dikes wherever found as the offshoots or apophysæ of larger igneous masses. These original bodies may not be apparent; indeed the extended development of dikes as along the Maine and New Hampshire sea coast and in the Lake Champlain region, with almost no evident parent mass, affords a most perplexing manifestation of igneous action, but it is reasonable to conceive of some such body below the surface. The question may be raised whether the simple fact of being offshoots of relatively small size is sufficient to warrant so radical an innovation as is implied in making them a grand division in the classification. If the separation does stand it involves the creation of a series of new families with their own names, on the analogy of the families of the two

[1] Massige Gesteine, p. 277.

grand divisions, plutonic and volcanic. The same magma appearing as a plutonic or volcanic mass might be followed out into its offsetting dikes, and these must logically then be set in an entirely different place in the scheme of classification. This involves a step so open to objection that it is doubtful if it will hold in the future.

It must be admitted, however, that grouping the dike rocks together has been of great service and has brought out relationships which it would have been difficult to detect without it. This is especially true of the basic dikes, and it has led, indeed, to the creation of all the kinds of rocks discussed in this paper except diabase. Where isolated dikes occur, with no discernible parent body, it is especially convenient. As such we have used it, but the writer does not believe it involves any other fundamental principle of classification. As now developed, the scheme of the basic or lamprophyric dike rocks would be the following: Under the lamprophyres are placed those dike rocks which contain a preponderating dark silicate. In all the structure is panidiomorphic or holocrystalline granular.

A. Syenitic lamprophyres, having an alkaline feldspar and biotite, hornblende and augite, one or all three.
   1. Minettes, with preponderating biotite, hornblende and augite subordinate.
   2. Vogesites, with preponderating hornblende or augite.

B. Dioritic lamprophyres, having plagioclase feldspar and biotite, hornblende and augite, one or all three.
   1. Kersantite; with preponderating biotite, a subordinate variety aschaffite, contains quartz, and others have olivine.
   2. Camptonite, with preponderating hornblende or augite, the two being commonly associated. Olivine is also frequently present and at times a little glass. The dark silicates are idiomorphic.
   3. Diabase dikes, holocrystalline, ophitic aggregates of plagioclase and augite, with occasional biotite and rarely hornblende. They do not differ essentially from effusive diabase. Olivine also occurs.

C. Monchiquite, plagioclase very subordinate and generally entirely lacking. Olivine, the diagnostic mineral in a more or less perfectly glassy base, with augite, hornblende and biotite, some or all. The base has often affinities with nepheline. A related rock with melilite has been called alnoite.

D. Fourchites, olivine subordinate or lacking entirely; base glassy or largely so; augite, hornblende and biotite, some or all present. A variety with excessively large amounts of biotite has been called ouachitite.

This arrangement has been in large part published by Rosenbusch, and the general scheme is his. The fourchite division has been created by J. F. Williams,[1] in connection with the dikes of Arkansas and in cooperation with the writer. But even before Dr. Williams's work began in Arkansas, and before Hunter and Rosenbusch had published Monchiquite, the writer had noted the corresponding types in the Lake Champlain region, and had sketched out some such subdivision. These conclusions were gladly placed at the disposal of Dr. Williams, and the table was extended by us as stated in his report in the endeavor to

[1] Ann. Rep. Geol. Surv. Ark., 1890, pp. 109, 110.

trace in the dike rocks varieties which would correspond to the peridotites and limburgites and the pyroxenites and augitites of the abyssal and effusive rocks. The same order is thus preserved, passing from diabase through monchiquite to fourchite. The theralites and basaltic nepheline rocks have also representatives in these two groups.

In the writer's opinion the most practicable future classification of rocks, as in the earlier part, will involve simply the two great divisions of plutonic (abyssal, tiefengesteine) and volcanic (eruptive, effusive), and that the dikes will merely be placed with the nearest related member of these as subordinate developments of the corresponding magma, in relatively narrow cracks or fissures. Since the above was written Zirkel's Petrography has appeared, and it omits dike rocks as a separate grand division.

## LOCAL GEOLOGICAL DETAILS OF THE DIKES.

### OUTLYING SOUTHERN EXPOSURES.

The dike on Dorset mountain (or Mount Eolus) in the town of Dorset, Vermont, is the most southern one here described. It was figured by A. D. Hager in the Vermont Report,[1] by whom it is represented as standing out in a limestone quarry with a columnar structure much resembling a cord of wood. It is 4 feet thick and consists of olivine, augite, brown hornblende, plagioclase, and a little isotropic base. It is an olivine-camptonite very like the dike from Campton, New Hampshire, called by Hawes olivine-diabase.[2] Prof. Seely, of Middlebury College, kindly gave us the specimen. (Fig. 2.)

The specimens from South Granville were given us by Mr. James W. Peets, on whose land they occur, and were discovered by Mr. Ira Sayles, of the U. S. Geological Survey. The dikes, of which there are several, run from 4 to 6 feet, strike northeast and dip 23° east. A small occurrence of mineral matter near them has created some local expectation of the precious metals, and some excavation has been made. This is a common experience throughout the entire section.

The dikes at Summit, Vermont, have already been correctly determined by F. L. Nason[3] to be typical camptonites.

The dikes at Fairhaven and Proctor exhibit hornblende, augite, plagioclase, and magnetite and are normal camptonites which have been likewise described in full.[4]

The dikes at the natural bridge on the Hudson, 6 miles from North River, New York, are porphyritic diabase. Mr. Nason, who kindly sent

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[1] Vol. II, p. 588.

[2] On a group of dissimilar eruptive rocks from Campton, New Hampshire. Amer. Jour. Sci., ser. III, vol. XVII, p. 14.

[3] F. L. Nason: A new locality for the Camptonite of Hawes and Rosenbusch. Amer. Jour. Sci., ser. III, vol. XXXVIII, p. 229.

[4] Kemp and Marsters: On certain Camptonite Dikes near Whitehall, Washington county, New York. Amer. Geol., Aug. 1889, p. 97.

us the specimen, writes that on the east bank and same distance below the bridge a dike 6 to 8 feet wide cuts the Laurentian limestone and gneiss, and that numerous others branch from this one.

HAMMONDVILLE, ESSEX COUNTY, NEW YORK.

In No. 7 slope of the Crown Point Iron Company's mines there are three dikes within 600 feet of the surface. They are 2 to 4 feet wide and in each case fault the ore raising it about 15 feet. They are all badly decomposed, but were originally diabase. A fourth specimen originally collected for a dike proves to be a portion of a shear zone and exhibits the minerals of the gneiss in an extremely broken and crushed condition along the line of faulting. The quartzes preserve their identity best. The crushed material from the other minerals has suffered extensive alteration and is now scarcely recognizable.

The dikes at Roe's spar bed[1] which is in the township of Crown Point, are badly altered diabase. They are three in number and strike N. 70° E. They vary from 8 inches to 2 feet, and cut a great pegmatitic mass of feldspar and quartz.

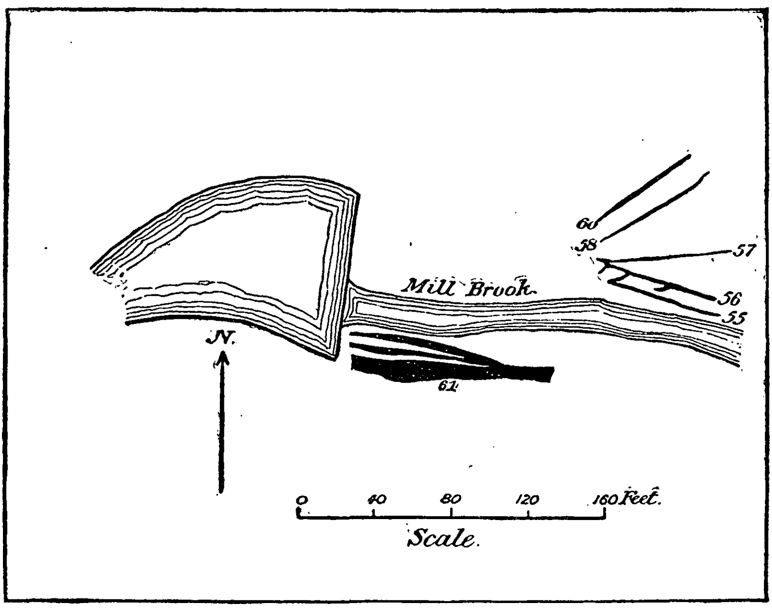


FIG. 3.—Sketch map of dikes on Mill brook, near Port Henry, New York.

PORT HENRY AND VICINITY.

A specimen of a dike 7 feet wide was given us by Mr. Uno Sebenius, mining engineer of Witherbees, Sherman & Co., from the Boonton place, Moriah Corners, 4 miles or more south of Mineville. It is an olivine-diabase. Two dikes are known in the Mineville mines, one

[1]Compare J. F. Kemp: Notes on the minerals occurring near Port Henry, New York. Amer. Jour. Sci., ser. iii, vol. XL, p. 62.

from the Miller pit is 4 to 5 feet and is a much decomposed diabase. The other, from the New Bed, we were unable to obtain. A dike is recorded in volume XV of the Tenth Census, p. 115, from the Lee mine. Rock from another was found by us on the dump of the Cheever mine, which proves to be an olivine-diabase with subordinate biotite. Several have been cut in the mine. The most interesting exposure at Port Henry is found 100 or 200 yards up Mill brook in the northern outskirts of the town. Immediately below a dam, as shown in the accompanying Fig. 3, a network of dikes pierces the gneiss. They run in a general east-west direction. Those on the north bank are from 6 inches to 2 feet thick, while the large one on the south bank is 20 feet, with two branches 2 feet each. All the dikes are diabase of somewhat abnormal structure.

### The Westport Dikes.

From 2 to 3 miles north of Westport and in the crystalline gneisses of Split Rock mountain five dikes are found. Three are just south of Barn Rock harbor, and two others are a mile further south. They are from 2 to 3 feet wide and consist of augite, largely idiomorphic, and often beautifully twinned, plagioclase rods, now much altered, and magnetite. One has numerous small brown hornblendes. The dikes may be considered as transition forms between the diabase and camptonite types. The country rock called gneiss above consists of common green hornblende, some pyroxene, plagioclase, garnet, and magnetite.

### The Split Rock and Essex Dikes.

These two localities are near neighbors, but are strongly contrasted in their geology. The promontory of Split Rock is formed by metamorphic rocks. The detached mass of Split Rock proper consists chiefly of crystalline limestone through which are distributed curiously contorted segregations of silicates that resemble snakes and are considered petrefactions by the natives. The limestone is thickly studded with irregular pyroxene (diopside) crystals that are passing into hornblende.[1] A band of rock 12 feet thick, striking N. 20° E. and dipping 45° SE., passes through the limestone and is visible on the north side of Split Rock. It consists of green hornblende, diallage, and plagioclase in a coarse allotriomorphic mass. It has many macroscopic points of resemblance to a coarse hornblende schist, but is not improbably a metamorphosed dike resembling those described by J. F. Kemp from the highlands of the Hudson river.[2] The crystalline limestone containing this rock is a mixture of calcite, garnet, and hornblende, which has altered from pyroxene and which often contains unchanged cores of the latter.

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[1] Compare G. P. Merrill on the Ophiolites of Thurman, Warren county, New York, etc. Amer. Jour. Sci., ser. iii, vol. XXXVII, p. 189.

[2] J. F. Kemp: The Dikes of the Hudson River Highlands. Amer. Naturalist, Aug., 1888, p. 695.

On the mainland, neighboring to the Split Rock itself (see Fig. 4), are clustered as many as ten dikes radiating in all directions. Nos. 510, 511, 512, 514, 515, 516, 517, and 520 are altered diabase. No. 513*b* is bostonite. In addition to these there are at 518 and 519, narrow seams of a very curious rock. They are a few inches wide and in the field were

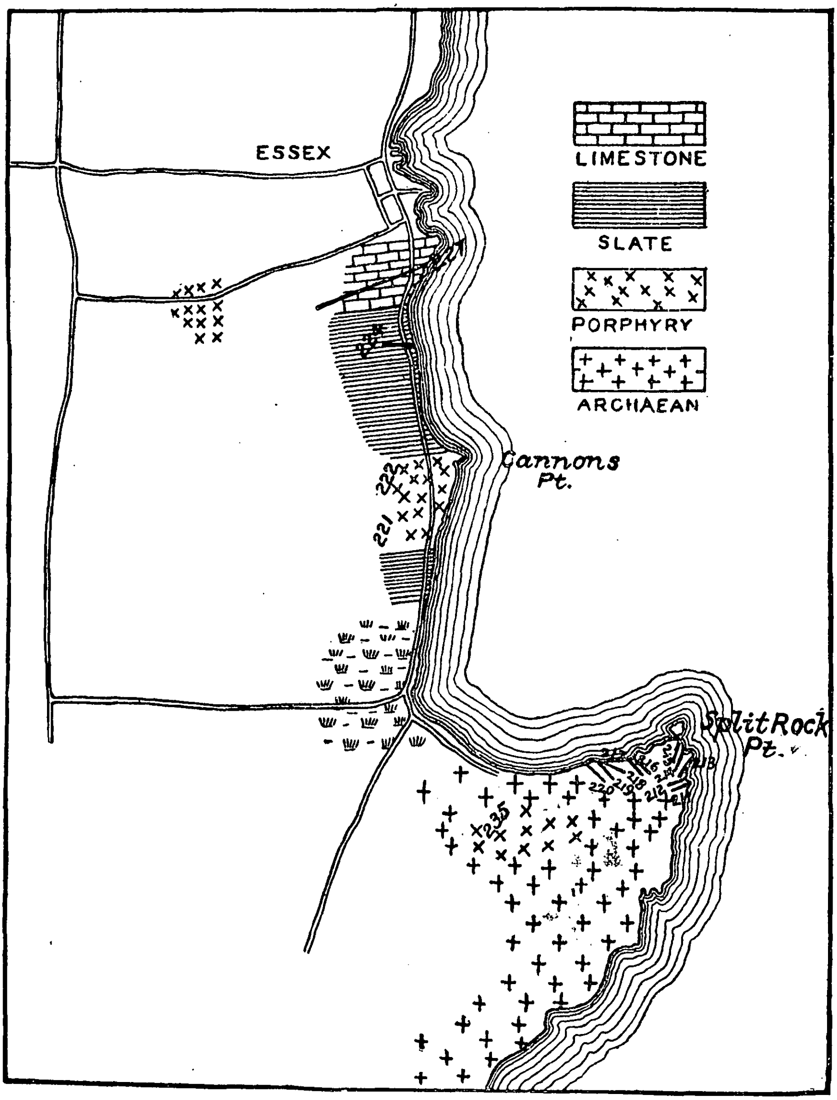


FIG. 4.—Sketch-map of dikes at Split Rock and vicinity, New York.

thought to be dikes. Under the microscope, No. 518 (7 inches wide) proves to be a rather coarsely allotriomorphic mixture of a feldspar and some dark silicate now altered beyond recognition. The feldspar presents an exceptionally fine illustration of the micro-perthitic intergrowth of two species in small lenticular individuals. The two can be distinguished without crossed nicols. No. 519 (2 inches wide) consists of green hornblende, plagioclase and very coarse grains of magnetite. These rocks are too coarsely crystalline to be narrow dikes, and are here regarded as small segregated veins which were formed in the general metamorphism of the region; but to this subject, as lying outside the province of the present paper, but passing attention has been given. Back on the ridge, as shown in the figure, is an outcrop of bostonite in numerous dikes that seam the mountain. They show the same trachytic structure as the general type described on page 18. They are undoubtedly a southern outbreak of the same mass that is seen in great development at Cannon's point, nearly 2 miles north.

The ridge of Split Rock mountain ends abruptly and is succeeded by a mile or less of meadow and marsh, which give way to the Utica slate. As stated by Emmons a large outcrop of slate occurs along the south shore. Cannon's point forms a small headland nearly 2 miles from Split Rock. To the south of it the slates appear as a low bluff along the shore. This increases at the point itself, where they are broken by a great sheet of bostonite which has apparently come up through a conduit near its middle portion and spread in all directions between the slates like a laccolite. The sheet is about 25 feet thick and undulates somewhat. The slates show both above and below. A general sketch of a portion is given in Emmons's Report, p. 85, which resembles the exposure to a considerable degree. As remarked by Emmons, the slates exhibit almost no evidence of any contact metamorphism. In thin section even the included fragments have sharp angular boundaries and ordinary fragmental structure. The sheet of the bostonite dips east under the lake. Under the microscope the rock shows the usual trachytic structure, but perfectly fresh specimens are not to be had on the outcrops The sections consist of a felt of feldspar rods with occasional large phenocrysts. Pyrite is present in small masses, together with limonite and a few shreds of some unrecognizable dark silicates, but as is universally the case with the bostonite outcrops the dark silicates are conspicuous for their absence. The sheet of bostonite[1] can be traced a short distance westward before it is covered. Another outcrop occurs nearly due west of Essex on the southerly of the two roads running west. This is a mile and a half from Cannons point and indicates, when taken together with the Split Rock exposure, that the outbreak was quite extensive. It is worthy of remark that the large outcrop just south of the Charlotte station is nearly due east of Essex and

[1] The rock is consistently called bostonite in the text, but it illustrates the weak point in the creation of a separate group of dike rocks. It certainly is in an interbedded sheet or laccolite; it has a well defined trachytic structure and could be called with perfect propriety trachyte if we disregard the now exploded time distinction between trachyte and porphyry—or it could be called porphyry if its pretertiary character is considered important, and yet why use trachyte or porphyry for sheets and bostonite for the same rock in dike?

that for a few miles north and south of this line the porphyries are most prominently developed. These relations will be again referred to in speaking of the east side of the lake.

The slates extend three-quarters of a mile north of Cannon's point and there abut sharply against the Chazy limestone which forms a bluff 50 to 75 feet high. The break forms as fine an illustration of a fault as could be desired. It has been figured in Emmons's Report, p. 272, and quite fully discussed, but the height of 150 to 200 feet attributed to the cliff is excessive. The same error is repeated in Macfarlane's Geological Railway Guide, p. 117. In the limestone to the north of the fault a dike of 2 feet (No. 527) occurs. What is probably a prolongation of it appears in the limestone quarries of Mr. Cowan, just southwest of the village (No. 583). Both these dikes are excellent typical camptonites. They have small hornblende prisms and fine plagioclase rods often exhibiting flow structure and at times a plumose arrangement resulting from it. An occasional larger hornblende appears and chloritic remains that may have been augite.

A mile and a half north of Essex, another bostonite dike appears in the shore (No. 526), which exhibits excellent flow structure of small feldspar rods around the large phenocrysts. A mile further a small stream enters the lake. In the banks of this, a short distance from the mouth and just east of the bridge where the highway crosses it, two large bostonite dikes (Nos. 528 and 529) appear, one of which is 30 feet wide. They break through Utica slate. Under the microscope they are seen to be much altered, and differ somewhat from the normal type. The groundmass consists entirely of small pseudo-spherulites which group themselves around the feldspar phenocrysts in a way characteristic of the prophyritic rocks. A bostonite dike is also to be found, we are informed by Mr. W. H. Benedict (late principal of the academy in Port Henry), in the quarries at Willsboro point, 6 or 7 miles north of Essex. We have a specimen of the rock which resembles the other bostonites very closely.

Some 3 miles west of Essex a considerable hill of norite projects above the later sedimentary rocks and is called Boquet mountain. On the north flank one narrow dike was discovered 1 foot wide in the norite. Its presence was revealed by the vegetation which formed a dark band across the bare norite, following the dike, the easier decomposition of the latter having formed a channel. The dike consists of idiomorphic brown basaltic hornblende crystals beautifully developed in two generations. They are frequently twinned parallel to $\infty P \bar{\infty}$ (100) and have a fluidal arrangement in the groundmass. This last is a glass, only transparent in the thin edges of the slide. No other minerals are present except magnetite. The dike thus corresponds to the hornblende-fourchites of J. F. Williams, as previously remarked.

THE DIKES ON TREMBLEAU POINT.

The sedimentary rocks, so prominent at Essex, run north to form Willsboro point and then terminate. The west shore of Willsboro bay is formed by the crystalline rocks, and these extend north along the lake shore to Port Kent, where the Potsdam sandstone comes in. A bold headland is formed just south of Port Kent by a spur of the Adirondacks, called Trembleau point. It has been opened up by the numerous railway cuts, and in the course of three miles some twenty dikes are revealed, as shown in the accompanying Fig. 5. They vary

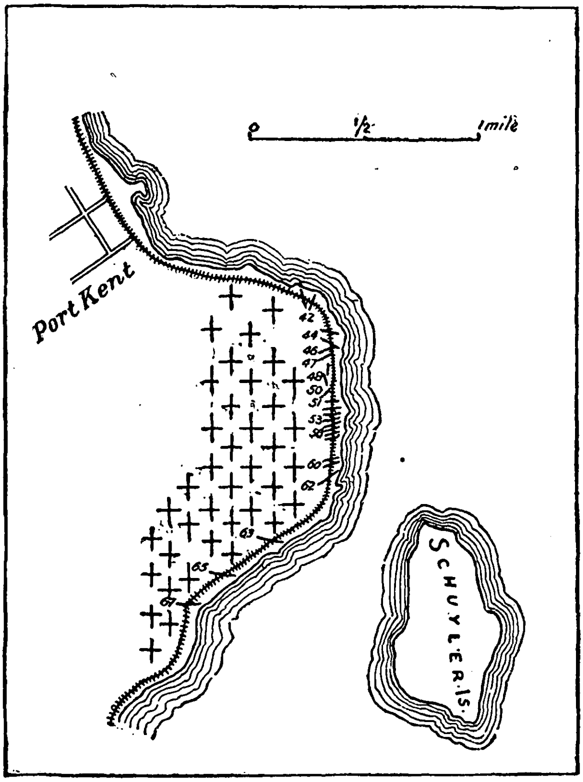


FIG. 5.—Sketch-map of dikes on Trembleau point, near Port Kent, N. Y.

from a few inches to more than 15 feet, and seam the apple-green norite with dark bands. They are very dense black rocks and only in the broader examples show their crystalline structure to microscopic observation. They are diabases when well developed and have the typical ophitic structure. The feldspars are lath-shaped and idiomorphic, and the augite is interstitial and allotriomorphic. The narrow dikes and the contact portions of the large ones show a marked change in structure due to the effects of chilling.[1] The dike becomes a dense

[1]Compare J. F. Kemp: Dikes at Kennebunkport, Maine. Amer. Geol., March, 1890, p. 137. In undescribed slides of dikes from the Archean of New Jersey the same phenomena appear.

mass of almost opaque glass, set with occasional plagioclase crystals and less frequent augite. The line of contact is at times marked by an excellent crushed strip (kataklas-Struktur) as shown in the accompanying drawing from a microphotograph, Fig. 6. Inclusions of norite often occur, being sometimes embraced by a forking of the dike like a horse in a mineral vein. Sections of such inclusions show them to have suffered much dynamic deformation. The plagioclases are strained and broken. Sections of the common norite exhibit much of a green pyroxene with the hypersthene. Its tint is like the green of hypersthene but it is entirely lacking in pleochroism. It also has inclined extinction. Garnets likewise occur in the norite which takes on at times a gneissic structure. It varies also in darker and lighter bands, which, however, are all essentially the same rock. (A great number of similar dikes were discovered in 1893 south of the above by Mr. T. G. White of Columbia College).

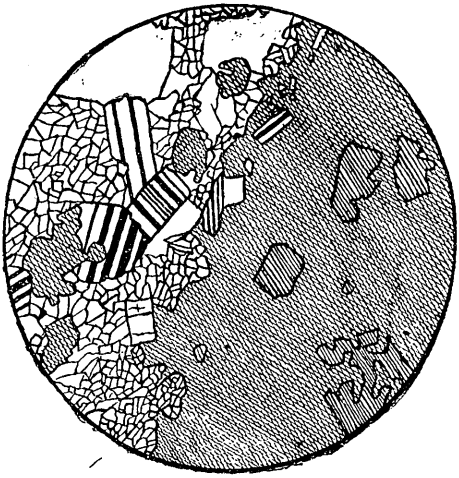

FIG. 6.—Micro-drawing of contact between a diabase dike and its norite wall, Trembleau point.

### THE DIKE ON VALCOUR'S ISLAND.

Through the courtesy of Prof. Henry Seely, of Middlebury, we have been given a specimen of a dike from the southern portion of Valcour's island, north of Port Kent, in D3 of the large map (frontispiece). While the record of dip strike and thickness is not available, a word may be said of its interesting general features. The rock consists of olivine, augite, and magnetite in a groundmass consisting chiefly of augite of the second generation, and some not abundant but feebly refracting mineral, probably nepheline. This we have classed with the monchiquites. The island is called by Emmons Calciferous, and is limestone.

### THE PALMER HILL DIKES.

Some 12 or 15 miles west of Port Kent is the town of Au Sable Forks, and a mile and a half west of the town is Palmer hill with its iron mines. These were first described by Emmons in the Report on the Second District, pp. 299, 300, and the dikes which cut them are there mentioned. They are again referred to by B. T. Putnam,[1] and the large dike has been microscopically determined by J. F. Kemp to be diabase.[2]

[1] Tenth Census, Vol. xv, pp. 118, 119.

[2] Amer. Jour. Sci., ser. iii, Vol. xxxv, p. 332.

Further study shows that this is its general character but that it contains biotite and scapolite (see ante, pp. 25, 26). Several smaller dikes also intersect the hill. The Rogers slope was down 1,600 feet on the incline and 400 feet vertically in 1889. It followed the large dike for 400 feet, and at this point a cross cut showed it to be 17 feet thick.

Other dikes are recorded by Emmons (op. cit., p. 293), as cutting the Arnold hill mines a few miles northeast of Palmer hill. These we have not examined, but it would seem from the analogy of the others that they must be diabase.

### THE DIKES AT LYON MOUNTAIN.

Lyon Mountain is a station on the Chateaugay narrow-gauge railroad, and is some 34 miles west of Plattsburg. It is the seat of the extensive iron mines of the Chateaugay Company. The mines afford some excellent exposures, as the magnetite bed is opened up along a line of 2½ miles. The best showing of dikes is made in the principal workings, of which the Hall slope intersects five, and near the mouth of the slope are several others. Their general relations are shown in the accompanying section (Fig. 7), which was sketched from a map of

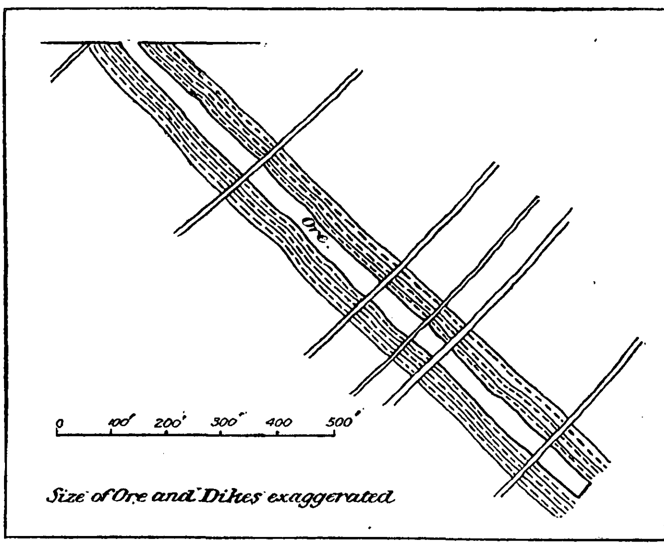


FIG. 7.—Cross-section of Hall slope, Lyon Mountain, New York.

the mine. The dikes were sampled by us underground. The ore and dikes strike in general N. 60° E. The former dips 45° and more north, while the dikes dip south at right angles with it. On a small scale they reproduce the relations of the dikes and beds of country rock in the Gogebic district of Lake Superior, as described by Van Hise.[1]

[1] C. R. Van Hise: The iron ores of the Penokee Gogebic series in Michigan and Wisconsin, Amer. Jour. Sci., Jan., 1889, p. 32.

The dikes may all be classed as diabase, but with some notable variations from typical examples. The augite shows a strong tendency to become idiomorphic, and thus to destroy the ophitic character of typical diabase. In one case, the first dike in the slope itself, the passage to a camptonite is well nigh complete. Small brown hornblende crystals have appeared in quantity, and the slide shows a rock formed of plagioclase, augite (unfortunately not fresh), hornblende, and magnetite. A similar association of such a hornblendic rock with diabase has already been noted by J. F. Kemp, at Kennebunkport, Maine.[1] As is indicated elsewhere in this paper, these two types of rock shade into each other with facility.

The dikes are very persistent, for all the neighboring slopes cut all of them.

### THE SOUTH HERO DIKES.

Several dikes are recorded in the Vermont Reports, vol. II, p. 585, from South Hero and the adjoining smaller islands, Stave and Savage. These are approximately shown on the large map in D 2 and D 3. We have visited the ones just south of the Sandbar bridge, and their general relations are shown in the small accompanying Fig. 8. No. 586 consists of large idiomorphic augite and olivine in a groundmass, consisting of small augites and some feebly refracting mineral, if not a glass. It is a monchiquite. The neighboring dike, No. 587, is an excellent diabase, with lath-shaped plagioclase and allotriomorphic augite. This close association of two different types is a striking phenomenon, and when one admits the usefulness of different names for different rocks, as these are, nevertheless their close genetic relations must at the same time be given due weight. Alteration is well advanced in No. 87 and has changed the augite in large degree to a deep, honey-yellow mineral, which polarizes as an aggregate, and which is considered serpentine. The Utica slate, in which the dikes occur, is greatly crushed and disturbed.

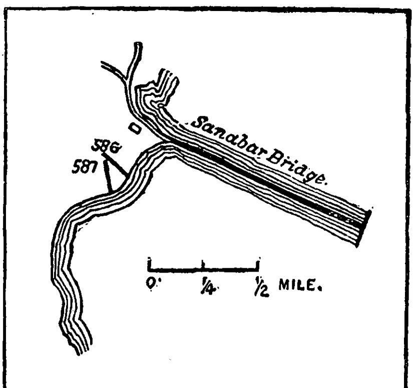

FIG. 8.—Sketch map of dikes near the Sandbar ridge, South Hero, Vermont.

Several dikes are recorded in the Vermont Report, vol. II, along the east shore of the lake between the Sandbar bridge and Burlington, as shown in the large map, in D 3. As these are in somewhat inaccessible points we have not visited them.

[1] J. F. Kemp: Trap dikes at Kennebunkport, Maine. Amer. Geol., March, 1890, p. 137.

THE DIKES OF BURLINGTON AND SHELBURNE POINT.

The region about Burlington and to the south for 10 miles along the lake shore is the most prolific in dikes of any part of the lake country, At Burlington the red quartzite, now recognized as Cambrian, forms the shore. To the west it is succeeded at Lone Rock point by the Hudson river slates and likewise by the rock on Shelburne (Pottier's) point. There is evidence of a fault along the line of Shelburne bay, for otherwise by the dips (as shown in the sections of the accompanying map, (Pl. II) the red sandrock should overlie the slates. This fault was recognized by Logan[1] in the early sixties and was traced a long distance south and north. The opposing dips in the section at the foot of Shelburne bay indicate a great disturbance of some character. On the small island just north of the section the dip is vertical and the strike has turned to N. 70° W. The sandstone shown in the section is not the red quartzite, but a white saccharoidal sandstone. It appears again in the section at Lone Rock point, north of Burlington. (Pl. III.)

The dikes of this region were mapped with considerable fullness by Zadock Thompson[2] as early as 1853. Observations, then unsystematic, were afterwards compiled by the same observer into a map, which appears as Plate XIV (misprinted IX) in volume II of the Geology of Vermont. The plate covers some outlying areas to the southeast, which we have not fully explored, and in the portion near the lake has been of the greatest assistance, and our indebtedness is here gladly acknowledged. Along the lake, however, as may be seen by comparing the two maps, we have found numerous dikes which do not appear in Thompson's map. The dikes at Nash's point are considered separately.

Immediately north of Burlington no dikes appear, but in the city, on the Williston turnpike, east from Spear street, is one 6 to 10 feet wide in blue limestone, and another of 2½ feet occurs on Spear street 1½ miles south. Three outcrop in the Willard's Ledge quarries. (Pl. IV.) Reproduced from a photograph is a view of No. 70 from the east, the quarry having worked in behind it. The dike is 5 feet thick and is exposed for 200 feet. It is a typical augite camptonite. Four more are to be seen in the Red rocks, south of Burlington, but the one (No. 3 of Thompson), said to be 12 feet wide,[3] we could not find. The widest is 6 feet and the narrowest 1 foot. Of the whole region, Pottier's or Shelburne point is most prolific in dikes. The point is a narrow

[1] W. E. Logan: The Quebec Group. Geol. Can., 1863.

[2] Zadock Thompson: Appendix to the History of Vermont. Burlington, 1853, pp. 52, 53. Our attention was called to this work, which is now a very rare book, by Prof. Perkins, of the University of Vermont, to whom we are indebted for many courtesies.

[3] See Geology of Vermont, vol. II. Table, p. 579. The record is doubtless a mistake.

peninsula of Hudson river slates, about 3 miles long. The dips and strikes are indicated by the sections and by the right lines of the map. The last outcrop, going west, of the red quartzite is at the foot of Sherburne bay, is a small exposure in a marshy meadow and is scored with glacial scratches. Around the shore we next meet the slates with the overlying white sandstone, but possessing a westerly dip. Two very peculiar dikes are met with not far from the foot of the bay, the southerly one is a yellow bostonite, and the northerly one is a breccia-bostonite. This latter (No. 7) is beyond doubt continuous across the point, and appears as No. 29 on the west side. Dike No. 9 of the map is on the outcrop merely a seam of limonite. No fresh material could be found on the surface. The outcrop looks like a vein of ore, but we believe it to be a weathered dike. On the highway is dike No. 100, a bostonite, but its width and strike are not now distinct. It is probably the same as Thompson's 39. Following the shore north, No. 11 is the porphyritic bostonite, described and analyzed on p. 20. No. 10 is undoubtedly continuous with No. 21, and consists of idiomorphic, brown, basaltic hornblende, and a little augite, in a groundmass of augites of the second generation, and glass. The analysis of No. 21, given on page 34, shows almost no alkalies. The olivine is not as abundant as in the typical specimens, but in other respects the dike is a fine example of hornblende-monchiquite.

The dikes on the end of the point, Nos. 12, 13, 14, 15, 16, 17, 18, are all basic and exhibit alternations between rocks with plagioclase and rocks without. Nos. 17 and 18 have plagioclase and are camptonites. All the others lack it and present beautiful idiomorphic hornblende and augite in a glassy base that in No. 14 gelatinizes. Olivine is present in all. They are therefore monchiquites. No. 12 and No. 17 afford particularly fine sections. Some of the small brown crystals may be biotite. From No. 22 and for a mile south the bank is thickly set with both basic dikes and bostonites. Nos. 30, 31, and 32 are monchiquites, which are poor in hornblende, but filled with beautiful zonal augites. Nos. 22, 23, 24, 25, 26, 27, 28, and 34 are bostonite of a prevailing light brown color. No. 23 pursues a sinuous course in the face of the bank, and No. 24 runs out to a feather edge. No. 26 forks, or rather seems to have come up in two branches which have united. No. 29 is a breccia porphyry and the continuation of No. 7.

### THE DIKES AT NASH'S POINT.

As Nash's point is reached the strike of the slates changes to N. 50° E., a difference of 30°. It is a small promontory included in the estate of Dr. W. Seward Webb, and presents some extremely interesting features. It was mapped by President Edward Hitchcock in the Vermont Report, vol. II, p. 585, but the sketch must have been made from memory, as the coast presents a quite different outline. This may be seen by comparing his map with the one here presented (Fig. 9), which is enlarged from the charts of the U. S. Coast Survey. We were unable to find dikes A and G of Hitchcock, but in other respects the essential features are accurately shown in the older report. Dike 102 is the very remarkable one that early attracted the special attention of President Hitchcock. As first pointed out by him, it is about 12 feet wide and is vertical. It consists of a bostonite base, which is thickly set according to the exposures visible at our visit, with rounded fragments of slate, red quartzite, and norite, one piece of which is 18 feet in diameter. President Hitchcock mentions, in addition, gneiss, hornblende schist,

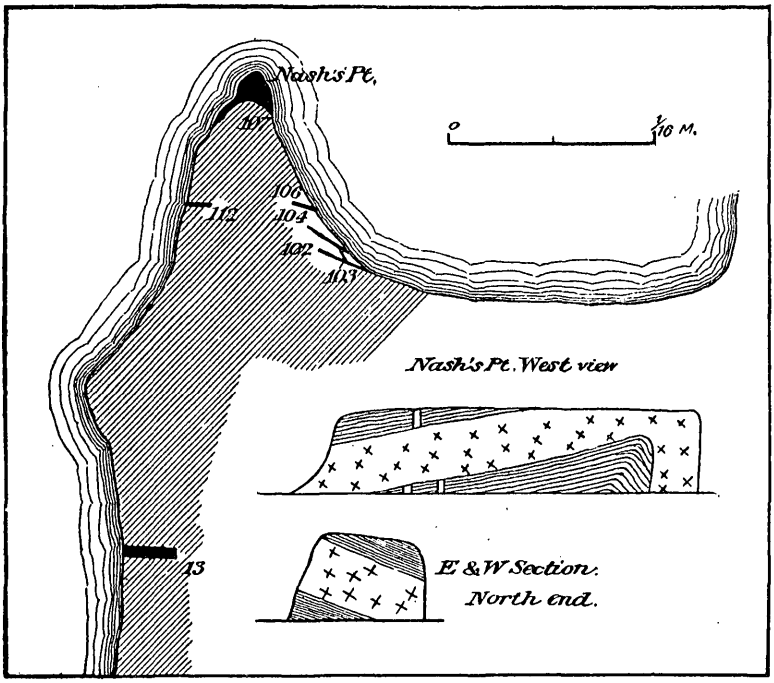


FIG. 9.—Sketch-map of dikes at Nash's Point, Shelburne, Vermont.

with garnets, quartz, gray sandstone, and black Trenton limestone. His granite is probably what we call norite. The slide shows plagioclase and garnet, but no dark silicates. These fragments are mostly in the interior of the dike. Some have a marked waterworn appearance, and resemble common bowlders; others are more angular. We regard the rounded ones to be due to the corrosion of the dike. In thin section all the inclusions show evidence of dynamic action. Cataclastic boundaries are common, and the plagioclases appear wrenched. The substance of the dike is largely minute feldspar rods and larger phenocrysts, around which the former show excellent flow structures. An analysis made years ago by Dr. Barker is given above on p. 20. The inclusions indicate that the dike has come from a great depth, and that it has passed through norite, gneiss, Cambrian strata, and slate.

President Hitchcock[1] has published a quite different view. Being impressed by the rounded and apparently water-worn character of the inclusions, he supposes them to have fallen into a fissure as a conglomerate. By some elevation of temperature the outer portions was fused or metamorphosed into the porphyritic base, while the inner parts (of an 11 to 12 feet dike) remained fairly intact, even though in part limestone; this, too, with intrusive trachytic dikes within a few feet. The thin sections (a modern resource not available in 1859) show that the base is certainly an intrusive rock, and so many absurdities are involved in the above, that the purely intrusive explanation seems to us the only one to adopt.

A narrow branch, 6 to 12 inches (No. 103) wide, connects No. 102 with No. 104. No. 104 is 2 to 4 feet and is the usual bostonite, but much altered. No. 106, just beyond, is 6 feet and is undoubtedly continuous with No. 112, on the opposite side. Both are bostonite. The end of the point is formed by an interbedded sheet, shown in west view and in east and west section. It is 10 feet thick and runs between the slates, following their southeast dip. It is abundantly set with slate fragments, and the slates at the bend are much broken and crumpled. The bostonite is the same as the neighboring dikes. No noticeable contact metamorphism could be detected. The most interesting feature is that the sheet cuts two basic dikes, one of which can still be traced in the thin cap of overlying slate. The basic dikes are thus older than the bostonite. This is the only outcrop which affords any indication of their relative age, and was first noted by Zadock Thompson. The basic dikes consist almost entirely of zonal augite. The base has suffered excessively from alteration. It polarizes as an aggregate, and is stained through and through with brown limonite. Some remains of olivine indicate that the rock was a monchiquite.

Southward on the shore a great 40 foot dike is exposed (No. 113), but as the walls are not well shown its relations can not be clearly made out. It is bostonite, with very large phenocrysts. It is excessively weathered. South again from No. 113, dikes are scattered at intervals. Dike 567, 1 foot wide, is a basic dike consisting of hornblende, augite, and olivine. Through the slide are patches of isotropic base, around whose edges are rhombs of secondary calcite, marking the progress of devitrification. Dikes 566 and 567 are bostonite, and are continuous. These are the least altered bostonite collected, and furnished the materials for the analyses given on p. 20 and the micro-photograph on p. 19. No. 570, 10 feet wide, and No. 571, of 4 feet, are both bostonite.

[1]E. Hitchcock: On certain Conglomerated and Brecciated Trachytic Dikes in the Lower Silurian Rocks of Shelburne, in Vermont, with special reference to the degree of heat at the time of their production. Proc. Am. Assoc. Adv. Sci., vol. XIV, p. 156.

No. 572, of 2 feet, not shown in the maps, is just north of Hill's point, and is an olivine camptonite.

Nos. 573, 574, and 575 form a small group less than a mile above Wing's point. Of these Nos. 573 (6 feet) and 575 (18 feet) are bostonite. No. 574 (20 feet) is a very typical camptonite, consisting of hornblende (but no augite appears in the slide), of plagioclase, and magnetite. The plagioclase affords scapolite in altering. The dike is one of the best camptonites discovered. No. 574 sends off a small branch (1 foot), which contains some augite.

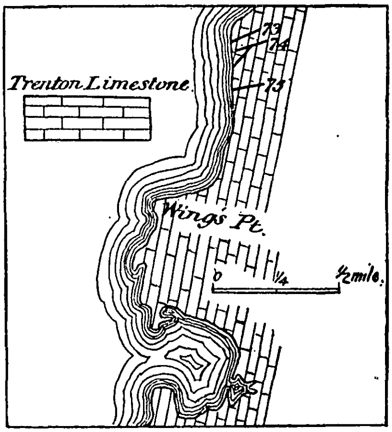

FIG. 10.—Sketch-map of dikes at Wing's point, Vermont.

Prof. Seely informs us that on the northwest side of Thompson's point, one or two bostonite dikes occur, but they escaped our observation; also that there is another dike in Ball's bay, of which we have a slide. It is bostonite.

Just north of Porter's bay a camptonite dike (3 to 4 feet), Nos. 577 and 579, cuts the point and appears on both sides. It intersects the limestone of the point next north of the one called Appletree point by Brainard and Seely.[1]

The limestones are Chazy and are near the celebrated exposures of Fort Cassin. South of Field's bay, on Summer point, is a dike (580) of bostonite recorded by Brainard and Seely, to whom we owe specimens. But still further south the Vermont shore is not favorable to the exposure of dikes. Rocky bluffs give way to beaches and cultivated fields.

At Charlotte, a station 12 miles south of Burlington, a knob of bostonite is found which covers about 20 acres and rises 150 feet above the plain. It is elliptical in outline and overgrown with woods. The exposed material is not fresh, but shows a porphyritic structure, with red and white feldspars.

## TABULATION OF THE DIKES.

In the following table the dikes are arranged in the same order as in the chapter on local geological details. Those south of the lake are first noted; next, those on the west side going north; finally, those on the east side coming south. Beyond question, many more will be discovered in the future.

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[1] Map in Bulletin Amer. Museum of Nat. Hist., Dec. 28, 1886, p. 297.

| Field Number. | Locality. | Width. | Strike. | Walls. | Name. | Remarks. |
|---|---|---|---|---|---|---|
| 126 | Mount Eolus (or Dorset mountain), town of Dorset, Vt. | 4 feet | | Marble | Olivine camptonite | Specimen from Prof. H. Seely contains olivine, augite, brown basaltic hornblende, plagioclase. Occurrence noted in Geology of Vermont, II, p. 587. |
| 00 | South Granville, N. Y. | 4 to 6 feet | NE., Dip. 23° E. | Slate | Augite camptonite | Others occur near. Specimens came from the farm of James W. Peets. |
| 00 | Summit, Vt. | 6 feet | NE | Quartzite | Camptonite | See F. L. Nason, New Locality of Camptonite, etc., Amer. Jour. Sci., Sept., 1889, p. 229. Mr. Nason gave us our material. There are many other dikes in the neighborhood. |
| 00 | Fairhaven, N. Y., two dikes | 3 to 4 feet | N. 40 E.<br>N. 80 E. | Slate | do | See Kemp and Marsters, On Certain Camptonite Dikes near Whitehall, N. Y., Amer. Geol., Aug., 1889, p. 97. |
| 00 | Proctor, Vt. | 3 feet | | Marble | do | See Kemp and Marsters, On Certain Camptonite Dikes near Whitehall, N. Y., Amer. Geol., Aug., 1889, p. 100. |
| 00 | Natural bridge, near North River, N. Y. | 6 to 8 feet | | Laurentian limestone and gneiss. | Porphyritic diabase | Specimens from F. L. Nason. |
| 160 | Hammondville, N. Y. | 2 to 4 feet | E. and W. | Gneiss and magnetite. | Badly altered diabase | The dikes are in No. 7 slope, and all fault the ore. |
| 161 | do | 2 to 4 feet | Vary | | | No. 162 is a shear zone and, though resembling a dike, is a crushed strip only. |
| 163 | do | 2 to 4 feet | | | | |
| 135 | Roe's spar bed, town of Crown Point, N. Y., near Moriah line. | 6 to 8 inches | N. 70 E. | Pegmatite segregation. | Diabase | Three narrow dikes of very badly altered diabase. See J. F. Kemp, Notes on Minerals occurring near Port Henry, N. Y.; Amer. Jour. Sci., July, 1890, p. 62. Also, E. H. Williams, idem, 3d ser., vol. XI, p. 273. |
| 136 | do | 1 to 2 feet | N. 70 E. | do | do | |
| 137 | do | 1 to 2 feet | N. 70 E. | do | do | |
| 553 | Boonton farm, Moriah Corners, N. Y. | 7 feet | NE. | Gneiss | Olivine diabase | Specimen given us by Mr. Uno Sebenius. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 554 | Miller pit, Mineville, N. Y. | 4 to 5 feet | NE. | Gneiss and magnetite. | Diabase | Badly altered. Another dike is reported from the New Bed mine. |
| 552 | Dump of Cheever mine | | | | Olivine diabase | Not found in place. |
| 555 | From a group on Mill Brook, in Port Henry, N. Y. | 1 foot | E. and W. | Gneiss | Diabase with idiomorphic facies. | |
| 556 | do | 10 inches | E. and W | do | do | |
| 557 | do | 2 feet | E. and W | do | do | All these are closely related, and form a nest of connected dikes just below a dam. |
| 558 | do | 1 foot. | E. and W | do | do | |
| 559 | do | 10 inches | E. and W | do | do | |
| 560 | do | 1 foot | E. and W | do | do | |
| 561 | do | 20 feet | E. and W | do | do | |
| 504 | Two miles north of Westport. | 2 feet | | do | Diabase verging on camptonite. | Two dikes with these were not cut for sections. The augite tends to become idiomorphic, and hornblende is occasionally present. |
| 506 | Just south of Barn rock harbor. | 3 feet | | do | do | |
| 507 | do | 3 feet | | do | do | |
| 510 | Split rock. See local map, p. 42. | 1 to 2 feet | NNE | Crystalline limestone. | do | Fresh material is difficult to obtain. |
| 511 | do | 1 to 2 feet | NNE | do | do | |
| 512 | do | 1 to 2 feet | NNE | do | do | |
| 513*b* | do | | NNE | do | Bostonite | Much altered. |
| 514 | do | 3 inches | N. and S | do | Diabase | Do. |
| 515 | do | 1 foot | N. and S | do | do | Do. |
| 516 | do | 8 inches | N. and S | do | do | Do. |
| 517 | do | 8 feet | N. and S | do | do | Probably diabase. Altered beyond recognition. |
| 520 | do | 4 feet | WNW | do | do | Do. |
| 535 | Inland west of Split rock | 6 inches | | | Porphyritic diabase | Much altered. |
| 536 | do | | | | Bostonite | Do. |
| 521 | Cannon's point, laccolite | | | Slate | do | Fresh material difficult to obtain. The sheet is 25 feet thick and 200 yards long. |
| 527 | Between Cannon's point and Essex. | 2 to 3 feet | E. and W | Limestone | Typical camptonite | This is one of the dikes selected as a type. |
| 583 | In Cowan's quarry, Essex | 2 feet | E. and W | do | do | Continuation of 527. |

| Field Number. | Locality. | Width. | Strike. | Walls. | Name. | Remarks. |
|---|---|---|---|---|---|---|
| 526 | 1½ miles north of Essex | | | | Bostonite | Exhibits good flow structure. |
| 528 | On a brook 2½ miles north of Essex. | | | Slate | do | Altered. |
| 529 | do | 30 feet | | do | do | Do. |
| 00 | Quarries, Willsboro point | | | | do | The specimen was given us by Mr. W. H. Benedict, of Elmira. |
| 584 | Boquet mountain, west of Essex. | 1 foot | N. 80 E | Norite | Hornblende-fourchite | The base is not isotropic. |
| 42 | Trembleau point, in second cut of D. and H. R. R., south of Port Kent. | 2 feet | N. 40 W | do | Diabase | The following twenty dikes are all diabase, with only such variations as are occasioned by narrow and broad individuals. The narrow show more or less glass from chilling. No. 47 contains inclusions of norite; 49 has unusually little feldspar. |
| 44 | Third cut south of Port Kent | 10 to 15 feet | | do | do | |
| 45 | 100 yards south of 44 | 6 inches | N. 80 W | do | do | |
| 46 | 100 yards south of 45 | 15 feet | N. 70 E | do | do | |
| 47 | 75 yards south of 46 | 15 feet | | do | do | |
| 49 | 50 yards south of 47 | 5 feet | N. and S | do | | |
| 50 | A short distance south of 49 | 6 feet | | do | No slide | |
| 51 | A short distance south of 50 | 6 feet | | do | do | |
| 52 | 20 yards south of 51 | 3 to 4 feet | E. and W | do | Diabase | |
| 55 | Just south of 52 | 2 inches | | do | do | |
| 56 | Just south of 55 | 3 to 4 feet | | do | do | |
| 57 | Near 56 | 1 inch | | do | Contact diabase | Narrow dike structure due to quick chilling. |
| 58 | Near 57 | 1 foot | | do | do | |
| 59 | 20 yards south of 58 | 15 feet | | do | Coarse diabase | |
| 60 | ½ mile south of 59 | 18 inches | | do | Diabase | |
| 61 | Near 60 | 4 inches | | do | No slide | |
| 62 | 300 yards south of 60 | 10 inches | N. 40 E | do | Diabase | Feldspars in radiating groups; also provided with dark cores. |
| 63 | ½ mile south of 62 | 15 feet | | do | do | |

| | | | | | | |
|---|---|---|---|---|---|---|
| 67 | South of 63 | 10 to 15 feet | | do | Coarse diabase | Hypersthene in concentrates; feldspar analyzed above, p. 24. |
| 590 | Valcour's island | | | Limestone | Monchiquite | Specimen given us by Prof. H. Seely. It affords a beautiful slide. It occurs in the south part of the island. |
| 600 | Palmer hill mines, near Au Sable Forks. | 17 feet | | Gneiss and magnetite. | Diabase | Contains biotite and secondary scapalite. Analyzed above, p. 26. |
| 120 | Lyon mountain, Clinton county. | 1 foot | N. 60 E | do | do | Badly altered. All the dikes from 120-130 cut the ore body of the Chateaugay mines. |
| 121 | do. | 2 feet | N. 60 E. | do | Diabase verging on fourchite. | |
| 122 | do. | 5 inches | N. 60 E | do | do | |
| 123 | do | 15 feet | N. 60 E. | do | Diabase verging on camptonite. | The augite is at times idiomorphic. Biotite is present. |
| 124 | do | 4 feet | N. 60 E. | do | Olivine diabase | 124 is at the bottom (1889) of the Hall slope. |
| 125 | do | 12 feet | N. 60 E. | do | do | |
| 126 | do | 7 feet | N. 60 E. | do | Altered beyond recognition. | The succeeding ones are intersected coming up to the surface. |
| 127 | do | 8 feet | N. 60 E. | do | do | |
| 128 | do | 6 feet | N. 60 E. | do | Diabase verging on camptonite. | Hornblende present. |
| 129 | do | 2 feet | N. 60 E. | do | Badly altered | |
| 130 | do | 1 foot | N. 60 E. | do. | do | Top of Hall slope. |
| 586 | South of Sand Bar bridge on South Hero island. | 18 inches | N. 40 W. | Shale | Monchiquite | The close association of two different species in 586 and 587 is remarkable |
| 587 | do | 2 feet | N. 5 to 10 W | do | Diabase | |
| 70 | Willard's ledge quarries. Burlington, Vt. | 5 feet | E. and W | Red quartzite | Augite camptonite | Typical dike of this species. There are two others, Nos. 71 and 72, near it. Two additional basic dikes, No. 74, on Spear street, $2\frac{1}{2}$ feet wide, and No. 75, on Williston road, 6 to 10 inches. |
| 1 | Red rocks, south of Burlington, Vt. | 1 to $1\frac{1}{2}$ feet | | do | Monchiquite | The groundmass of many of the following dikes is not perfectly isotropic, but shows tendencies toward nepheline and plagioclase. The olivine is inferred from alteration products. |

| Field Number. | Locality. | Width. | Strike. | Walls. | Name. | Remarks. |
|---|---|---|---|---|---|---|
| 2 | Red rocks, south of Burlington, Vt. | 2½ feet | | Red quartzite | Monchiquite | |
| 3 | do | 6 feet | | do | do | |
| 4 | do | 2½ feet | | do | do | |
| 5 | Southwest corner of Shelburne bay. | 1 to 2 feet | NNW | Slate | Bostonite | |
| 7 | do | 10 feet | E. and W | do | Breccia-bostonite | No. 7 is continuous with 29. |
| 10 | East side of Shelburne (or Pottier's) point, south of shipyard. | 6 feet | N. 60 W | do | Hornblende monchiquite | Good type and a very interesting rock. |
| 11 | do | 20 feet | N. 50 E | do | Bostonite | No. 11 has large feldspar phenocrysts and is like a coarse feldspar porphyry. |
| 12 | East side of Shelburne (or Pottier's) point, north of shipyard. | 3 to 4 feet | N. 70 W | do | Monchiquite | |
| 13 | do | 2 to 3 feet | N. 65 W | do | | |
| 14 | East side of Shelburne (or Pottier's) point, on end of point. | 3 to 5 feet | N. 60 W | do | Monchiquite | Shows columnar partings. |
| 15 | West side of point | 1 foot | | do | No specimen | |
| 16 | do | 1 to 2 feet | N. 60 W | do | do | |
| 17 | do | 8 to 10 feet | N. 70 W | do | Augite camptonite | Contains some base. |
| 18 | do | 2 feet | | do | do | |
| 19 | do | 6 inches | N. 75 W | do | do | Branch of 18. |
| 21 | do | 8½ feet | N. 80 W | do | Hornblende monchiquite | Continuation of No. 10. |
| 22 | 1 mile south of White's island | 5 to 7 feet | N. 60 W | do | Bostonite | |
| 23 | South of 22 | 1 to 5 feet | N. 80 W | do | do | Pinches from 5 feet to 1 foot. |
| 24 | Few feet north of 23 | 0 to 6 inches | N. 80 W | do | do | Narrow dike pinches out. |
| 25 | 300 yards south of 24 | 6 feet | N. 80 W | do | do | Two dikes each 6 feet with 3 feet of slate between. |
| 26 | 50 yards south of 25 | Irregular | | do | do | No specimen. |
| 27 | 100 yards south of 26 | 2 to 5 feet | N. 80 W | do | do | Do. |
| 28 | 10 yards south of 27 | | | do | do | No specimen; one larger dike and various small offshoots. |

| | | | | | | |
|---|---|---|---|---|---|---|
| 29 | 200 yards south of 28 | 20 feet | N. 45 W | do | Breccia bostonite | Continuation of No. 7. |
| 30 | 75 yards south of 29 | 5 feet | N. 45 W | do | Monchiquite | |
| 31 | 300 yards south of 30 | 4 feet | N. 80 W | do | do | |
| 32 | Branch of 31 | $1\frac{1}{2}$ inches | | do | do | |
| 33 | Near 32 | 6 feet | | do | Bostonite | |
| 34 | 300 yards north of Nash's point. | 5 feet | | do | No specimen | |
| 102 | Nash's point, on the estate of Dr. W. Seward Webb. | 12 feet | N. 70 W | do | Breccia bostonite | Contains most interesting inclusions, see text. |
| 103 | do | 6 to 12 inches | N. 20 W | do | Bostonite | |
| 104 | do | 2 to 4 feet | N. 50 W | do | do | |
| 106 | do | 6 inches | E. and W | do | do | |
| 107 | do | 10 feet | | do | do | Dike passing into an interbedded sheet. See map in text. |
| 108 | do | 2 feet | E. and W | do | Monchiquite | 108 and 109 are faulted by the later porphyry. |
| 109 | do | 2 feet | E. and W | do | do | |
| 112 | do | 8 feet | N. 80 E | do | Bostonite | Continuation of 106. |
| 113 | Webb estate, south of Nash's point. | 40 feet | E. and W | do | do | The dike may be wider. |
| 567 | $\frac{3}{8}$ of a mile south of 113 | 1 foot | E. and W | do | Hornblende monchiquite | Both augite and hornblende in two generations. |
| 566, 565 | $\frac{3}{4}$ of a mile south of 567 | 15 to 20 feet | N. 50 E | do | Type bostonite | 566 and 565 are the same dike. They are the freshest and serve as types. |
| 570 | $\frac{3}{4}$ of a mile south of 566 | 10 feet | E. and W | do | Bostonite | |
| 571 | Near 570 | 4 feet | E. and W | do | do | |
| 572 | Further south | 2 feet | E. and W | do | Camptonite | Contains olivine and both hornblende and augite. |
| 573 | Wing's Point | 6 feet | N. 70 E | Limestone | Monchiquite | |
| 574 | do | 20 feet | N. 70 E | do | Type camptonite | Hornblende, no augite |
| 575 | do | 18 feet | E. and W | do | Bostonite | |
| 577 | Just north of Porter's bay | 4 feet | N. 70 E | do | Augite camptonite | 577 and 579 are probably continuous. |
| 579 | do | 3 feet | N. 70 E | do | do | |
| 580 | Summer's point, near Fort Cassin. | | | do | Bostonite | May have contained dark silicates. Specimen given us by Prof. H. Seely. |
| 581 | Ball's bay | | | do | Red bostonite | 581 and 582 were given us by Prof. H. Seely. |
| 582 | do | | | do | White bostonite | |

# INDEX.