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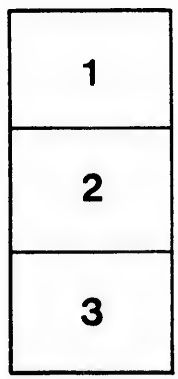
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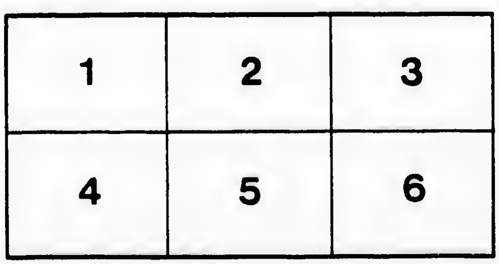
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CONTRIBUTIONS FROM THE GEOLOGICAL DEPARTMENT OF COLUMBIA COLLEGE.

No. XXX.

The Effusive and Dyke Rocks near St. John, N. B.

Thesis

SUBMITTED BY

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FELLOW IN GEOLOGY,

In partial fulfilment of the requirements
for the
Degree of Doctor of Philosophy, in the University Faculty of Pure Science of
Columbia College, 1895.

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THE EFFUSIVE AND DYKE ROCKS NEAR ST. JOHN, N. B.

W. D. MATTHEW.

Read by title, March 17th, 1895.

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1. Reports of the Geological Survey of the Province of New Brunswick, 1839–43, by Abraham Gesner.

2. Observations on the Geology of Southern New Brunswick, by L. W. Bailey, G. F. Matthew and C. F. Hartt.

3. On the Azoic and Palaeozoic Rocks of Southern New Brunswick, by G. F. Matthew. Quar. Jour. Geol. Soc. XXI., 422.

4. Remarks on the Age and Relations of the Metamorphic Rocks of New Brunswick and Maine, by Geo. F. Matthew and L. W. Bailey. Proc. Am. Ass. Adv. Sci. 1869, 179.

5. Preliminary Report on the Geology of Southern New Brunswick, L. W. Bailey and G. F. Matthew. Can. Geol. Sur. Rep. 1870–1, p. 13.

6. Summary of Geological Observations in Southern New Brunswick, by L. W. Bailey and G. F. Matthew. Can. Geol. Sur. Rep. 1874–5, p. 84.

7. Report of Geological Observations in Southern New Brunswick, by L. W. Bailey, G. F. Matthew and R. W. Ells. Can. Geol. Sur. Rep. 1875–6, p. 348.

8. Report on the Pre-Silurian (Huronian) and Cambrian or Primordial Silurian Rocks of Southern New Brunswick, by L. W. Bailey. Can. Geol. Sur. Rep. 1877–8, p. 1–34 DD.

9. Report on the Upper Silurian and Kingston (Huronian) of Southern New Brunswick, by G. F. Matthew. Ib. p. 1–6 E.

10. Report on the Geology of Southern New Brunswick, embracing the counties of Charlotte, Sunbury, Queens, Kings, St. John and Albert, by L. W. Bailey, G. F. Matthew and R. W. Ells. Can. Geol. Sur. Rep. 1878–9, p. 1–26 D.

11. On the Progress of Geological Investigation in New Brunswick 1870–1880, by L. W. Bailey. Proc. Am. Ass. Adv. Sci. 1880, p. 415.

12. On the Progress of Geological Investigation in New Brunswick. Trans. Roy. Soc. Can. 1889, VII., Sec. 4, 3–17.

13. Cambrian Organisms in Acadia, by G. F. Matthew in Trans. Roy. Soc. Can. 1889, Sec. 4, p. 135.

14. Correlation Papers, Archæan and Algonkian, by C. R. Van Hise. U. S. Geol. Sur. Bull. 86. 1892.

15. Matthew, W. D., Intrusive Rocks near St. John, N. B. Trans. N. Y. Ac. Sci. XIII., 185. 1894.

16. Outlets of the St. John River, by G. F. Matthew. Nat. Hist. Soc. New Bruns. Bull. XII., 1895.

The present paper is a continuation of a petrographic study of the igneous rocks near St. John, N. B. The intrusive rocks in the immediate neighborhood of the city have already been discussed;* it remains to describe the surface volcanics and dykes, and to add some notes as to the further extension of the intrusives.

Pre-Cambrian volcanic rocks are known to exist at various points along the flanks of the metamorphic belt of eastern North America. Although more or less clearly recognized as such in many of the earlier surveys, their certain determinations could usually be made only by the aid of thin sections, and accordingly it is only within the last few years that their exact character has been definitely known. The late Dr. Geo. H. Williams, in an article in the Journal of Geology,† has called attention to their wide distribution and importance, and to their close resemblance to modern effusives, except where altered by metamorphism. Dr. Williams gives a very full and complete summary of their occurrence in Newfoundland, Nova Scotia and New Brunswick, the eastern townships of Quebec, in Maine, New Hampshire and eastern Massachusetts, in the South Mountain of Pennsylvania and Maryland, and along the Blue Ridge as far south as Georgia. There is, however, a great dearth of petrographic descriptions of these rocks, most of the determination having been made in the field only. Besides the well known

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*Trans. N. Y. Acad. Sci. XIII., 185.

†Jour. Geol. II., 1.

work of Dr. Williams* and Miss Bascom† on the South Mountain volcanics, and the studies of Wadsworth,‡ Diller § and Sears ‖ in the Boston Basin, the only descriptions of ancient effusive rocks from the eastern coast of which the writer knows are the recent article of Dr. Bayley ¶ on the spherulitic felsites from Vinal Haven, Me., and a few descriptions of porphyries from the eastern townships by Dr. Adams**. There is, no doubt, other work of the kind in preparation, and quite probably other published descriptions exist, which have escaped this review; still the scantiness of petrographic descriptions of these early volcanics of the east coast, in comparison with those from other parts of the United States, is rather remarkable.

In Southern New Brunswick the so-called Huronian has been believed from the first to be in large part volcanic, and was so described in the reports of the different surveys.

The first systematic survey was made by Dr. Abraham Gesner for the Provincial Government in 1838–42, its results being published in five reports dated 1839–43, inclusive. Dr. Gesner was greatly impressed with the important part which had been played in Southern New Brunswick by volcanic forces, which, however, he was inclined to over-rate, ascribing to them many of the effects due to erosion. Speaking of the southern part of the province he says:

"At the southeastern base of this elevated region" (the granite area which divides Southern from Central New Brunswick) "the slates and limestones of the transition series, and the sandstones and conglomerates of the secondary formations, are placed in their usual order of succession, wherever they have not been broken up and buried by extensive eruptions of volcanic matter. All these rocks have been penetrated by large and numerous dikes of trap, basalt and pophyry (*sic*), and the surface of the country with all the islands in the Passamaquoddy Bay exhibit the clearest evidences of having been the theatre of violent earthquakes and intense volcanic action."††

Although some of the massive rocks which Dr. Gesner believed igneous have been since shown to be of sedimentary origin, yet his estimate of the importance of eruptive rocks in this

* Amer. Jour. Sci. XLIV., 482.

† Jour. Geol., I.

‡ Bull. Mus. Comp. Zööl. Harv., V., 275; Proc. Bost. Soc. Nat. Hist., XXI., 288.

§ Bull. Mus. Comp. Zööl. Harv., VII., 165.

‖ Bull. Mus. Comp. Zööl. Harv., XVI., No. 9; Bull. Essex Inst., XXVI., 118 etc.

¶ Geol. Soc. Amer., Baltimore Meeting, Dec., 1891.

** Can. Geol. Sur. Report of 1839, p. 12.

†† Report of 1839, p. 12.

part of the Province still holds good. But it is evident from the tone of his writing that he considered the volcanic outbursts as of far later date than that now assigned to them, for he connects these disturbances with recorded earthquakes and changes of level in New Brunswick within historic times, and even pictures a number of supposed volcanic cones near Great Salmon River, east of Quaco.*

In the Dominion Government Survey Reports, Dr. L. W. Bailey and G. F. Matthew recognize the existence of great amounts of volcanic ash, as well as massive lavas, porphyritic and vesicular. But the greater part of the series, consisting of fine-grained rocks denoted as *felsite* and *petrosilex*, remained to the last of doubtful origin, with an apparent tendency in Dr. Bailey's later report (1877–8), written after a most careful and thorough study of the volcanic hills, to consider them as largely sedimentary rocks, though formed under special conditions of deposition; † while Dr. Ells ‡ considers them as volcanic. In his latest paper bearing on this subject § Dr. Bailey points out the need of microscopic sections of these rocks, both to make sure of their character and perhaps to determine also whether certain members are of pre-Cambrian age or are identical with very similar rocks of later origin. He summarizes the character and relations of the pre-Cambrian rocks as follows:

"Among these Archæan rocks at least two great groups of sediments are to be distinguished, which, in a general way, bear many features of resemblance to those which in other parts of Canada are known as the Laurentian and Huronian systems. At the same time it is impossible . . . not to see that . . . there are equally striking differences, . . . especially seen in the greater proportionate amount of distinctly stratified rocks, such as slates and quartzites, in the comparative absence of coarsely crystalline deposits of crystalline minerals and ore beds, and in the much greater regularity and uniformity of the whole . . . Another desideratum in connection with these two ancient systems is a better understanding of their time relations to each other, for though no doubt is entertained by the author as to the fact that the felsitic and schistose rocks referred to the Huronian are more recent than the granitoid and gneissic rocks and the great belts of crystalline limestone which have been regarded as Laurentian, a contrary view has

* Report of 1840, p. 21.

† Can. Geol. Sur. Rep. 1877–8, p. 1, D. D. In a foot-note at this page, Dr. Selwyn compares this series to the ancient volcanic rocks of England and Wales, with which he believes they are identical in origin.

‡ Ib., p. 3 D.

§ Trans. Roy. Soc. Can., 1889. Vol. VII., Sec. 4, p. 3.

been taken by others; while neither has any satisfactory contact of the two formations been observed, nor an instance in which the conglomerates of the one are unquestionably made up of material derived from the other." *

Collections made during the past three summers and studied by the aid of the microscope have amply confirmed the views held as to the volcanic origin of the greater part of the "Huronian." It will be seen that a considerable variety of igneous rocks is represented, including lavas and ash rocks once precisely like those of modern times and not greatly altered by metamorphism. Many of the fine grained felsites and much of the petrosilex, however, cannot be certainly determined, even with the aid of thin sections; but judging from the almost complete absence among them of distinctly recognizable sediments, it is probable *that the greater part of the doubtful ones should be considered as altered ashes or tuffs.*

The pre-Cambrian of Southern New Brunswick falls naturally into two great divisions: a lower one composed of gneisses, limestones, quartzites and various schistose rocks, usually highly crystalline, but of distinctly sedimentary character; and an upper one composed chiefly of volcanic products, fading out above into more normal sedimentary beds which are as a rule much less altered than those of the lower series. The lower group has been compared to the Laurentian; the upper has been called Huronian; but both these names are dropped in the later Survey Reports and replaced by numbers for the different groups. In the present paper they may be occasionally used as indicating this two-fold division, but not implying any correlation in the present restricted sense of the terms.

The Laurentian series includes divisions 1 and 2 of the later reports; the first being granitic gneiss and granite, which is, near St. John at least, intrusive in Division 2, and may be placed provisionally between it and the volcanic series. Division 2 is clearly sedimentary, and shows a varying amount of regional metamorphism, being at times comparatively little altered.

The upper series or "Huronian" includes at least three subgroups. These are:

1. *Coldbrook* (Div. 3). This is composed almost entirely of volcanic rocks—lavas, ashes and tuffs. The most abundant types of rock are felsites and "petrosilex" (fine-grained, flinty quartz-felsite), often porphyritic and accompanied by much agglomerate and finer grained ash-rocks into which they seem to grade. Dr. Bailey also mentions various sedimentary rocks from

* Loc. cit., p. 5.

this group: although the sections examined by the present writer have so far failed to show any distinctly non-volcanic clastics. The Coldbrook is exposed over a considerable area northeast and east of the city, making up the greater part of the pre-Cambrian hills in that direction, where its best exposures lie. To the west it is of less importance.

2. *Coastal* (Div. 4). Overlying the Coldbrook is another series of rocks, more altered in its typical exposures than the lower group. Its lower part * is made up of volcanic rocks entirely similar to those of the Coldbrook, from which the writer has not been able to distinguish it. The upper part, however, is composed chiefly of sedimentaries, with some volcanics interbedded. The prevailing schistose structure of most of the rocks of this group in the area examined renders it very difficult to determine their nature without the aid of a thin section in each individual case; hence the proportion of volcanic rock is not very well known. It is often difficult, indeed, even with a thin section, to say whether a rock of this kind is altered felsite, or ash, or volcanic debris recomposed by water and approximating normal sediments.

3. *Kingston* (Div. 5). This is a more altered series than either of the other two, and occupies a strip of land some five miles wide, bounded on either side by a fault line,† and not less than 70 miles in length. Its rocks embrace recognizable surface volcanics, porphyritic lavas and felsitic ash rocks, and also altered types, basic and acid schists, some of which were certainly of volcanic origin, and quite probably all. The relations of the Kingston to the other pre-Cambrian rocks are very uncertain. Dr. Bailey says:

"The same uncertainty rests upon the age of the so-called Kingston group of southern New Brunswick, and which in its western extension becomes in part at least continuous with that to which Prof. Shaler assigns the name of 'the Campobello Series.' By that author..... they are regarded as being Lower Cambrian, but as beds of very similar character occur within a very short distance of the known Cambrian of St. John, and yet bear very little resemblance to it, this supposition seems untenable. As they are certainly older than the Silurian, and in all probability not Cambrian, they must be regarded as pre-Cambrian, the view adopted in the Survey Reports, or as Cambro-Silurian."‡

* As defined by Prof. Bailey in the Report for 1877-8.

† G. F. Matthew, Bull. Nat. Hist. Soc., N. B. XII., 16.

‡ Trans. Roy. Soc. Can. 1889, Sec. 4, p. 8.

The thickness of this series is very great; at New River the section is over eleven thousand feet,* supposed to have been de-deposited in a gradually sinking area, bounded by the faults on each side. The immense erosion which this this series has suffered probably is the key to its more altered character, the rocks now at the surface having been very deeply buried.

4. *Etcheminian.*† This is a series underlying the Cambrian slates in most of their exposures, and unconformable both to them and to the Coldbrook rocks on which it rests. The rocks are wholly sedimentary in their typical exposures, but are believed by G. F. Matthew to have been rapidly deposited by the working over of the softer volcanic beds, and to indicate a time of dying volcanic activity. There is reason to believe that part of the diabase which lies below the Cambrian at St. John is post-Etcheminian (possibly post-Cambrian as well). This series is considered by the last named author to be probably equivalent to the upper part of the Coastal; if so it has considerable directly volcanic material in it.

To sum up, the pre-Cambrian near St. John includes the following groups:

A.—LAURENTIAN.

1. *Portland group*, including Div. 2, with probably parts of Div. 1 in other localities than St. John.
2. *Intrusive granite* and quartz-diorite; perhaps later than the position here assigned to it.

B.—HURONIAN.

3. *Coldbrook group* or Div. 3, of volcanic rocks.
4. *Coastal group* or Div. 4, of volcanic and sedimentary rocks, in its upper part probably equivalent to the next group.
5. *Etcheminian* or *Basal Series*, of sedimentary rocks, underlying the St. John group.
6. *Kingston group* or Div. 5, of metamorphosed volcanics. Of very uncertain relations; may be post-Cambrian.

UPPER LIMIT OF THE PRE-CAMBRIAN.

The Cambrian is here considered to be limited by the unconformity at the base of the St. John group. The criterion given by Mr. Walcott for determining the base of the Cambrian, namely the lower limit of the Olenellus fauna, cannot here be applied, as Olenellus has not been found in New Brunswick, though a large pre-Paradoxidean fauna of very primitive type

* G. F. Matthew, Can. Geol. Sur. Rep. 1887-8, p. 1E.
† Trans. Roy. Soc. Can. 1889, Sec. 4, p. 135.

has recently been worked out in Div. 1*b* of the St. John group.* Mr. Walcott † includes the Etcheminian, which contains a few fossils, none satisfactory as determining its relations, in the the Cambrian period. In this case it would become a question as to how much value can be assigned to the unconformity between the Etcheminian and the *volcanic* rocks beneath, and whether the latter might not also be included in the Lower Cambrian. Between the Laurentian and all the later rocks there appears to be a great break, if one may judge from lithologic characters and the lack of conformity in dip in many places.

Satisfactory conglomerates are, as might be expected, lacking at the base of the volcanic series. In some observed cases the rock nearest the contact is a breccia (volcanic); but it is not known whether any of these contacts are not obscured by thrust-planes. That the St. John group is separated from the Laurentian by a great break there is good evidence; a conglomerate at its base has been observed to contain pebbles of the Laurentian rocks.‡

CLASSIFICATION.

It has been thought most convenient in the present paper to discuss the igneous rocks of the Coldbrook, Coastal and Etcheminian together, dividing them according to physical characters, and subsequently to take up the Kingston rocks as metamorphosed phases of these. It is found that the division into *Acid* and *Basic Effusives*, used by Dr. Williams for the igneous rocks of South Mountain, is a very convenient one to employ here, the intermediate types being but poorly represented. The dykes, clearly recognizable as such, are discussed separately, as is also an occurrence of soda granite which has been referred to the Huronian in the Survey Reports. In order to give some clear understanding of the character of the rocks included under these divisions they have been placed in groups which in the sections studied are fairly distinct one from another. It has not been possible to make any well founded generalizations as to the distinctness of these groups in point of time, still less as to their succession. The arrangement is as follows:

EFFUSIVE ROCKS.

A.—*Acid Effusives.*

1. *Quartz Porphyry.* Compact, quartzose, full of phenocrysts.

* These Transactions, Vol. xiv., April, 1895.

† Correlation Papers—Cambrian, U. S. G. S. Bull., 81.

‡ Trans. Roy. Soc. Can., 1889, Sec. 4, p. 139.

2. *Felsite porphyry.* Few phenocrysts, many characters of surface flows. This includes nearly all the acid effusives, and laps over on the one hand into quartz-porphyry and on the other into an acid porphyrite.

B.—*Basic Effusives.*

1. *Diabase.* This is the chief type.
2. *Feldspar-porphyrites*, including a few basic lavas, strongly porphyritic, purplish in color.

DYKE ROCKS. Only basic dykes are known.

1. *Diorite-porphyrite* and Camptonite.
2. *Diabase* and various porphyrites.
3. *Augite-porphyrite.*

SODA GRANITE.

QUARTZ-PORPHYRY.

Two occurrences in the Quaco Hills, one on the Upper Quaco Road, the other near Golden Grove, seem to merit special notice. The porphyry is even grained, compact and homogeneous, with abundant phenocrysts of quartz and orthoclase, the quartz predominating. No characters of surface flows were observed; the rock appears not to grade into the felsites and ash-rocks in which it occurs, and may be in both cases an intrusive sill or a heavy dyke of post-Coldbrook age. It is very similar in character to the quartz-porphyry ("claystone-porphyry"), which occurs at the base of the Siluro-Devonian in Western St. John County (Dipper Harbor Road).

Under the microscope this rock shows abundant quartz phenocrysts, somewhat corroded at times, but usually with well marked crystal outlines. They show what seems to be a polysynthetic twinning, very fine and faintly marked, visible in sections approximately basal. This may be the rhombohedral twinning mentioned by Prof. Rosenbusch * as occurring in quartz-porphyry. The orthoclase phenocrysts are rather less abundant than quartz; they are usually once twinned, and present no special feature worthy of note. Dark silicates are absent in the sections examined. Iron ores occur in scattered granules. The *groundmass* is microgranitic and of very even texture, composed of quartz and untwinned feldspar.

The color of this rock in its freshest occurrence is a bright pinkish-red; near Golden Grove it is pale green, weathering to brown, and much altered.

* Mikrosk. Phys. der Massigen Gesteine. p. 355.

FELSITE-PORPHYRY. Pl. XII., XIII., and Fig. A p. 199.

Under this group may be placed the majority of the effusives of the Huronian. Most of the "felsites" and "petrosilex" of the Canadian Survey Reports are either porphyry or porphyry-ash; and some of the rocks described as sandstone, etc., prove on the evidence of thin sections to belong here. The central and most abundant type is a quartz-free porphyry with scattered phenocrysts of orthoclase and plagioclase in a microgranitic or microfelsitic groundmass. Quartz phenocrysts occur in a few sections; in others the amount of twinned feldspar increases relatively to the untwinned till the rock is, strictly speaking, a porphyrite. Flow structure is seen in most of the sections, and trichites, spherulites, perlitic cracks and other characteristically volcanic structures have been observed. Breccias are abundantly found, sometimes very coarse, the fragments being six inches to two feet in diameter. Finer grained rocks, sometimes distinguishable as composed of sharp-edged angular fragments, more often not determinable, are still more common. From the absence of any accompanying rocks of distinctly sedimentary character it is perhaps safest to place these as in most cases fine ashes or tuffs.

This group of rocks bears every indication of being of strictly superficial origin. Their texture is more or less irregular; they are frequently vesicular and flow-brecciated, with few scattered and often broken phenocrysts, being contrasted in these characters with the compact, smooth and uniform appearance and abundance of phenocrysts seen in the last group.

Quartz phenocrysts occur quite rarely, are often broken, but seldom notably resorbed. The quartz in the groundmass is more important. In perhaps a third of the sections examined it seems to be an essential constituent, distinguishable from the feldspars by its brighter polarization colors; it is granular and rarely at all intergrown in granophyric forms. In many cases it is certainly a devitrification product, as is shown by the remnants of original glassy structures still traceable.

Orthoclase phenocrysts are found sparsely scattered in all the sections. They are never very large, mostly 1–4 mm. in length, are rarely resorbed, but not uncommonly broken and the fragments displaced. They are usually twinned after the Carlsbad law, in one case after the Baveno. The orthoclase in the groundmass is mostly granular, but part of the rod-like feldspar in the groundmass of some sections may be monoclinic.

Plagioclase is in some sections more abundant than orthoclase, and rarely entirely fails. Its crystals are less regular in outline than the orthoclase. In the groundmass it sometimes occurs in granular form, being then in some cases, probably in all, of secondary origin (the rock being a consolidated ash). More generally it is seen as little rods lying in a granular mixture of less well individualized feldspathic material.

The *ferromagnesian silicates* are almost entirely wanting. This may be due in part to alteration, but they evidently were never in any considerable quanity. In one instance (Spec. 340 from east of Coldbrook Station), a quartz bearing porphyry with an unusual abundance of phenocrysts, biotite has been observed, now colorless from alteration, but still retaining its optical characters and form.

Magnetite and other iron ores occur commonly, mostly in very small grains. It is frequently titaniferous, as shown by its weathering to leucoxene.

The special interest of this group of rocks lies in the characteristic structures noticeable in them. These afford conclusive proof that the rocks were ejected on the surface and probably in part under water, and that they were originally very like modern volcanic products—acid lavas, scoriaceous, glassy and brecciated towards the surface, more compact and porphyritic below.

Perlitic cracks (Pl. XIII., Fig. 1) appear to be preserved in several specimens, but in one only were they clearly and certainly determined. This is part of a "felsite" outcrop on the Hammond River below Upham; this felsite is strongly flow-lined, somewhat brecciated and spherulitic in parts. The perlitic cracks are preserved in some brilliantly polarizing mineral (calcite ?), and are most easily seen with crossed nicols, though they are visible in ordinary light.

In the same flow are the best preserved examples of large spherulites that I have seen from New Brunswick (Pl. XII., Fig. 1). These are rather irregular in form, seldom complete, but retain a radial structure. They shot out from various solid bodies in the magma, feldspar phenocrysts, grains of magnetite, etc., paying no regard in their growth to the flow-lines already existing. The rods of quartz and feldspar seem now to be broken down into elongated granules with straight lateral edges (Fig. A); but there is no evidence in the specimen that this was not the original structure of the spherulites. The groundmass in which they occur is micrograntic, and, along with the spherulites themselves, is filled with minute trichites, seen in Fig. A, composed of one or more curving black needles shooting out from a grain of magnetite. These needles are now partly broken up into a succession of granules, like a string of beads; in other parts they are unchanged. They are evidently earlier than the spherulites, for they show a general direction following that of the flow lines, without regard to the spherulitic structure.

Microspherulites, showing the revolving cross under crossed nicols have been observed in a red felsite from Hanford Brook, collected by G. F. Matthew. Nodular felsites, in which the radial structure is not seen, occur in several places. This structure in English rocks is believed by some authorities to be generally secondary, arising from a progressive alteration of the rock proceeding from a central vesicle or some point of weakness. From the traces of radial structure preserved, it seems probable that, in some instances at least, the nodules in New Brunswick felsites are altered spherulites of large size. At Shanklin, near

FIG. A. *Trichites in spherulitic felsite. Spec. 664. Magnified 133 diameters.*

Quaco, is a bright red nodular felsite forming an outlier in Subcarboniferous shale. It is lithologically like the volcanic hills near by, and probably of the same age. The nodules in this rock are strongly marked in the weathered specimens, from the abundance of hematite in their outer zones; they often fall out of the matrix on slight weathering, being apparently more silicified and better able to resist alteration. They have usually a central filling of feldspathic material free from iron; the iron has collected chiefly at their surfaces. In thin sections traces of a radial structure seems to be preserved in the arrangement of the secondary hematite flakes. The whole substance of the rock is much silicified, but both in the transparent centres and in the deeply stained outside a minute pilitic structure is retained, apparently of feldspar rods arranged approximately parallel to the flow lines. If the apparent remains of radial structure are not illusory, this would seem to indicate either:

1. That a radial spherulitic structure could form in a rock already in large part crystallized, or
2. That this pilitic structure of the groundmass may be of secondary origin.

Of these two, the former supposition seems to the writer the more probable one.

The Survey Reports mention in general terms,* and in one case more particularly, gradations of these felsites into the holocrystalline rocks with which they are in places associated. Dr. Ells speaks of these holocrystallines as basal portions of volcanic flows; Dr. Bailey† considers that north of the Germaine Brook as an extreme case of metamorphism. The present writer has not yet been able to obtain a complete series showing this gradation, though a partial one was made at Germaine Brook. But in none of the felsites sectioned is there evidence of gradation into crystalline rocks, either by slower cooling or subsequent metamorphism. That such deeper-seated facies of the Huronian igneous rocks exist there can be no doubt, and it would probably be revealed by more extended study.

The acid *breccias* and *ash-rocks* are very abundant. Coarse felsite breccias occur east of Coldbrook, where they contain larger rounded or pear-shaped masses, probably volcanic bombs; on the road skirting the south flank of Bloomsbury Mountain, here composed of a pale greenish-gray silicified felsite, strongly flow-lined and perhaps a devitrified glass; at Titus' Mill on the Hammond River, here being partly a devitrified glass breccia; in a railway cutting near Henry Lake, and elsewhere. The finer breccias or coarse ash-rocks are sometimes schistose, as for instance, a greenish-gray breccia not far east of Coldbrook. With increasing fineness they are more and more altered and less easy to recognize, the fine-grained, flinty felsites and petrosilex showing no characteristic structures which can be considered original.

These fine-grained rocks often show aggregations of chloritic material in rounded or irregular spots with fairly well defined outline. Aside from this they are uniformly micro-crystalline in structure, made up of feldspar with a quarter or less admixture of quartz, and scattered magnetite grains. Occasional large grains and porphyritic crystals of feldspar are seen in some specimens.

* Ells, 1877-8.

† Bailey, 1877-8. Discussed in this paper under soda granite.

DIABASE.

Except the felsites this is the most abundant rock of the Coldbrook group, and forms also a considerable part of the rocks referred to the Coastal series in 1887–8. It occurs as surface flows as well as intruded sills and dykes. At Racehorse Point, east of St. John City, it crops out on the shore as a heavy dyke in the coarse green and red sandy slates that are overturned on the fine grey slates of the St. John group.* This dyke has baked the adjoining slate into a hornstone very like the edges of the igneous rock itself, and the contact of the two is not easy to distinguish. Dr. Gesner in 1840† mentions it as a dyke, but supposes that it has fused the slate near by, and thus effaced the line of contact. The Survey Reports‡ do not recognize it as a dyke, but consider it, apparently, as an altered sediment or ash-rock. In thin section, however, it is unmistakably a diabase, and on careful examination the line of contact with the slates was traced on each side. Under the microscope this contact is perfectly sharp and clear, the igneous rock being dense, almost opaque, with scattered plagioclase phenocrysts. The slate does not show much change; the parallel arrangement of the granules is not noticeable, and minute grains of a brightly polarizing mineral are developed near the edge. The diabase of the central parts of the dyke is tolerably fresh; the augite occasionally shows crystal outlines, but mostly moulds the feldspar. No olivine was observed, but a peculiar oil-green substance, indistinctly fibrous or matted, with a high refractive index and bright aggregate polarization, appears occasionally, and is probably an alteration product of olivine, perhaps allied to Becke's *pilite*.

At some little distance back from the shore, near the penitentiary, the diabase crops out again, here being in part a surface flow, finer grained and strongly vesicular, and separated by a sharp line of contact from the coarser, non-vesicular diabase lying northwest of it. The latter contains included masses of white-weathering flinty felsite, which seem to belong just north of it, and are very like the supposed ash-rocks underlying the Etcheminian north of the city.

From the foregoing it is clear that a part of the diabase, the dyke on the shore and the heavier dyke or sill back of it, must be later than the slate and felsite through which they cut. Of the relative age of the vesicular diabase there is no good evidence; though it appears to be older than the sill. The slate is

* Trans. Roy. Soc. Can. 1890, Sec. 4, p. 127.
† Geol. Sur. Prov. New Bruns., Rep. 1840, p. 11.
‡ Geol. Sur. Canada, Rep. 1871, p. 137.

considered Etcheminian by G. F. Matthew* ; hence this diabase is post-Etcheminian, possibly Cambrian or later.

Provisionally it may be placed as pre-Cambrian.

The diabase is again well exposed on the west side of the harbor of St. John, in a series of hills on the southeast border of the Cambrian valley. It is made up, as far as can be seen, of a number of surface flows, which are accompanied by a little slate, apparently interbedded, and were perhaps partly sbumarine. The characters of surface flows can be seen in some others of the many outcrops that occur in all parts of the Huronian hills,

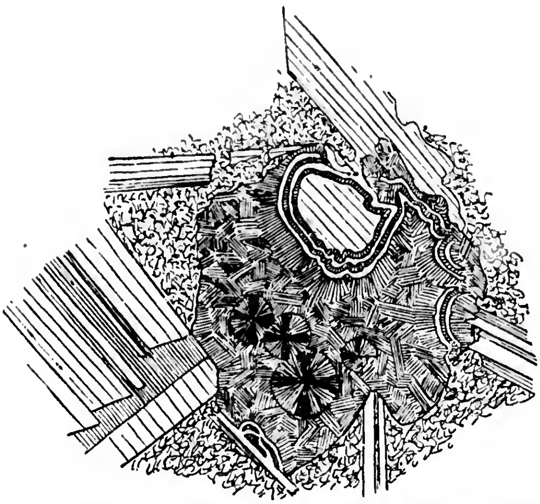

FIG. B. *Vesicle in diabase, showing agate-like banding of feldspar (?) and chlorite. Magnified 70 diameters. Spec. 150.*

others are more probably intrusive sills. All are normal diabase, without olivine, and with an almost colorless augite. The vesicles are mostly lined with quartz, and filled with chlorite, sometimes with hornblende. The chlorite is very often spherulitic and shows the beautiful Berlin-blue polarization color. Secondary growths of a mineral which seems to be plagioclase are known; it is not twinned, but appears to be sometimes optically continuous with the feldspar rods around the vesicle. It

* Trans. Roy. Soc. Canada, 1890, Sec. 4, p. 127.

is at times intergrown in alternate concentric layers with the chlorite of the vesicles, as is shown in Fig. *B*.

Basic *ash rocks* occur abundantly and can sometimes be seen to be made up of diabase fragments. But most of them are too far altered to be certainly identified.

PORPHYRITES.

Under the group may be placed a considerable number of outcrops of strongly porphyritic basic effusives, mostly of purplish black color and not certainly known to grade into the diabases. They form heavy beds, apparently thick surface flows, very vesicular for the most part and containing phenocrysts of plagioclase which in one case, a porphyrite from south of Golden Grove, are remarkably fresh and glassy.

Under the microscope they show a somewhat ophitic fine-grained groundmass composed of feldspar rods, minute grains of augite and magnetite in which are scattered the feldspar phenocrysts, those in the rock from Golden Grove being of the *microtine* habit, water clear, repeatedly twinned and somewhat corroded. No augite phenocrysts were seen. In a porphyrite from near Henry Lake the vesicles are filled with a zeolite, determined as thompsonite on its micro-characters.

METAMORPHISM.

The alteration as seen in these Coldbrook and Coastal rocks is very varied in amount. *Devitrification* is universal; in no instance has any trace of remaining glass been identified. The resultant microcrystalline mass varies in texture from a microfelsite, in which the minerals are scarcely distinguishable to a moderately fine microgranite, in which are local accumulations of coarser grains. Shearing occurs sometimes in the porphyries, quite generally in the ash-rocks. In the Coastal especially, it is usually so much developed as to produce a schist. The last named alteration is accompanied by the production of great amounts of epidote; this mineral occurs less abundantly in the massive flows. Uralitic hornblende is a frequent alteration product of the diabase, retaining usually the form of the augite which it replaces. In no observed case is the change carried so far, either in the acid or basic rocks, as to produce a strongly schistose or subgneissic structure. It is not intended to assert that such rocks may not occur locally, but only that they are evidently not usual.

SODA-GRANITE. Pl. XVI. and XVII.

A high ridge stretching from Hardingville on the Germaine Brook to the great bend in the Hammond River below Upham consists of a red granitic rock called syenite (hornbende-granite) by the Survey officers, but which on microscopic study appears to be an augite-soda-granite. The Germaine Brook and Hammond River run at the foot of its steep eastern slope; on the other side lies a broken country, little opened up. The rock was considered by Prof. Bailey as an extremely metamorphosed phase of the breccias and felsites which surround it; and he cites instances of the transition of the one into the other, which the writer has not yet been able to completely follow. *

In regard to Prof. Bailey's conclusion, it must be observed that microscope sections have failed to show any extreme metamorphism in the Coldbrook or Coastal groups. They have frequently a secondary cleavage developed, which often amounts to an imperfect schistosity. But of the entire re-formation of the minerals in the rock so as to make a gneiss, still less a granite, I have seen no instance in the post-Laurentian rocks of this region. If the rock is not a subsequent intrusion, the view of Dr. Ells, stated with regard to a number of such areas of crystalline rocks occurring near the borders of the volcanic areas, seems more acceptable. † He regards them as being basal parts of volcanic flows, their crystalline character being due to slow cooling.

Prof. Bailey describes the passage from felsite into "syenite," as follows:

"With the dark grey petrosilex are irregular beds of pale red and red felsite, which in approaching Titus' Mill become at the same time more frequent and more crystalline. In some portions . . . a distinct but usually highly contorted stratification is discernible, but other portions are quite homogeneous, and by admixture of a dark green mineral resembling hornblende become imperfect syenites. . . . It is supposed that these syenitic hills . . . are simply the petrosilex and breccia in a more altered form. That they are in great part of fragmentary origin is very evident, and even where apparently most crystalline a rounding of the grains of quartz, and the occurrence of irregular cavities or vesicles suggests that all have been produced by like agencies." ‡

The microscopic appearance of the "syenite" throws consid-

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* Geol. Sur. Can. Rep., 1877-78, p. 8, DD.

† Geol. Sur. Can. Rep., 1877-78, p. 3. D.

‡ Loc. cit.

erable new light on its origin. In thin section (Pl. XVI., fig. 1) it appears as a rather coarse but very even-grained soda-granite, apparently of igneous origin, the quartz often granophyric (whence the rounding of its grains of which Dr. Bailey speaks); the dark silicates are augite and brown and green hornblende, the two latter apparently secondary after augite. The feldspar is partly idiomorphic, partly granophyric or granitic. Towards the edges of the mass the rock becomes fine-grained, and shows in thin section (Pl. XVI., fig. 2) a mass of interlacing rods of feldspar with comparatively little quartz, and augite in small irregular granules. The characters cited are sufficient to show that this rock has cooled from fusion. Did it occur in the midst of highly metamorphic rocks, gneisses and crystalline schists, it might well be supposed that its fusion was but an extreme phase of metamorphism. But in view of the slightly altered character of the rocks surrounding it, it seems almost certain that the fusion was followed by a notable displacement, and the rock is therefore a stranger in its present association and must be classed as igneous. The peripheral phases, as far as noted, accord with this view; we find there a rock approaching a porphyry in structure, instead of a gneiss. How nearly the granite is connected with the felsites around it, it is not now possible to say.

Microscopic characters. The rock is an *augite-soda-granite*, containing at most, perhaps, one-third free quartz, and a varying amount, sometimes quite small, of ferromagnesian silicates. In its central parts it is strongly granophyric (Pl. XVII.); towards the edges it loses that feature and finally becomes fine-grained with a rod-like form to the feldspars, and almost no quartz.

The *quartz* calls for no especial comment. It is, as noted, largely intergrown with the feldspar; when not so, it appears to have been the last constituent of the rock to form, never showing crystal outlines.

The *feldspar* is partly a twinned feldspar, apparently anorthoclase, and partly untwinned. Much of it is so altered by kaolinization that its nature cannot be determined; the more altered parts are made almost opaque by the presence of minute red flakes (hematite ?). The untwinned feldspar rarely shows crystal outlines and is often intergrown with quartz. The twinned feldspar shows an exceedingly fine and regular twinning with a small extinction angle, and occurs mostly in idiomorphic crystals imbedded in the quartz-orthoclase mass. From the regularity and fineness of its twinning this feldspar is considered to be more probably anorthoclase than a fine grained plagioclase.

Besides the anorthoclase, a few crystals of the ordinary plagioclase type were observed.

Augite occurs in poorly developed crystals or irregular grains, almost colorless and with no apparent pleochroism. It is mostly altered to hornblende, chlorite or epidote. In the strongly granophyric specimens the augite and other ferromagnesian silicates are in very small amount.

Brown hornblende. A pale brown hornblende, with a very high extinction angle, 25° maximum, occurs in moderate amount. It is in part at least secondary after augite, but some of it seems to show its own crystal outlines, and if so, may be considered original. Its pleochroism is:

𝔞—faint brownish yellow,
𝔟—pale reddish brown,
𝔠—pale yellowish brown,

$$\mathfrak{a} > \mathfrak{b} > \mathfrak{c}.$$

Green hornblende. This is in varying quantity, and appears to be in all cases paramorphic after augite and brown hornblende. It has the usual colors and pleochroism of uralitic hornblende, though its structure is almost compact. The stages in the alteration of the augite appear to be,

1. Brown hornblende,
2. Green hornblende, sometimes bleached before passing into
3. Chlorite.

Epidote occurs as an alteration product, but apparently not of this series; the conditions of its formation must have been different. In some sections no augite or brown hornblende is found, but only an aggregate of green hornblende, epidote and chlorite.

Apatite is an abundant accessory, in the usual long prisms, which are rather more abundant in the quartz.

Magnetite occurs in small irregular masses and is in part titaniferous. *Pyrite* is occasionally to be noticed.

Zircon appears in every section examined in crystals of square cross section. In the concentrates these are seen to be made up of the unit prism and pyramid, rarely showing their edges in the slightest degree modified. This character of the crystals is much in contrast with the rather abundant zircons of the intrusive granite-diorites of the Laurentian. The latter have the unit and second-order prism and unit pyramid much modified by development of several other faces, giving them a rounded outline, while the zircons of the soda-granite are sharp-edged and clean cut. The difference in character may perhaps be due to the conditions of solidifying, more probably to the chemical composition of the magma.

In the concentrates a few grains are found of a mineral with ultramarine-blue color, and pleochroism ultramarine to colorless. This is thought to be probably a soda-hornblende, allied to glaucophane. Its refraction and polarization indices are about those of hornblende and it is (?) biaxial; but its properties could not be further determined.

The peripheral phases of the soda-granite are not thoroughly known. The complete gradation from it into the felsite-breccia described by Dr. Bailey as occurring at Titus' Mill, the writer has not succeeded in finding. At other points the granite was seen to be fine-grained and to have lost its characteristic bright red color. It was not at all gneissic, however, nor was it strongly porphyritic, and of further transition between it and the felsites no trace was seen.

Under the microscope (PL. XVI., fig. 2) this fine-grained facies shows a more or less panidiomorphic structure of feldspar crystals which exhibit a decided tendency towards the rod-like form. One or two large crystals appear to be porphyritic in the rest of the mass. The feldspar is largely plagioclase, the rest orthoclase, no anorthoclase being certainly recognizable in the sections. Augite? appears in minute grains scattered all through the mass; they are too small to show well the characteristic optical properties, and have little or no crystal outline.

An analysis was made of the soda-granite from above Titus' Mill, spec. 661. This was a fairly average specimen, moderately granophyric, with an unusually large amount of dark silicates present. The following results were obtained (column I.):

Analyses of Soda-granites.

I. Titus' Mill, Upham, N. B.
II. Kekequabic Lake, Minn. U. S. Grant.
III. Pigeon Point, Minn. W. S. Bayley.

	I.		II.	III.
	a	*b*		
SiO_2	64.86	64.79	66.84	72.42
TiO_2	0.70	0.63	.....	0.40
Al_2O_3	15.02		18.22	13.04
Fe_2O_3	5.53	5.60	2.27	0.68
FeO	1.01	0.86	0.20	2.47
MnO	0.18	0.40	.....	0.09
CaO	2.61	2.63	3.31	0.66
MgO	1.42	1.51	0.81	0.58
Na_2O	3.92	3.93	5.14	3.44
K_2O	2.37	2.35	2.80	4.97
CO_2	0.55		.....	.....
P_2O_5	.....		tr	0.20
Loss on ign.	1.73	1.78	0.46	1.21
	99.89		100.05	100.37

With this analysis are placed for comparison analyses of anorthoclase granites from Kekequabic Lake* (II.) and Pigeon Point† in Minnesota (III.). The Upham rock agrees fairly well in composition with that from Kekequabic Lake, being somewhat lower in alkalies and alumina and higher in iron percentage. Dr. Grant describes the latter rock as dull pink in color, feldspathic, with abundant augite and comparatively little quartz, and shows that it is an intrusive rock, exhibiting porphyritic facies. It would seem to be less altered than our rock, and consequently has a much larger proportion of augite; otherwise the resemblance is quite close.

The results of separation with potassio-mercuric iodide solution were as follows:

Sp. g. 2.54—2.57	2. %
2.57—2.62	26.
2.62—2.67	41.
2.67—2.70	7.
2.70—2.73	6.
2.73—3.16	10.
> 3.16	8.
	100

The part falling between 2.62 and 2.67 was chiefly quartz and impure feldspar. The feldspar between 2.57 and 2.62 was analyzed with the following results:

SiO_2, 66.62; Al_2O_3, + Fe_2O_3, 21.22; CaO, 0.82; MgO, not det.; Na_2O, 6.73; K_2O, 2.10.

In its outward appearance and in many details of its structure this soda-granite is very like the "red rock" of Pigeon Point, in Minnesota, so fully described by W. S. Bayley.‡ Dr. Bayley determined the red rock as an anorthoclase granite with porphyritic phases.

Dr. Bayley shows that the red rock is to be considered as a contact product resulting from the complete fusion of red sandstones by an intruded gabbro. If the view held by Prof. L. W. Bailey as to the origin of the soda-granite be correct, there is a further likeness to the Pigeon Point rock, as the metamorphism which could produce a rock of such type must be supposed pushed to the point of fusion. For reasons already stated, however, the writer is unable to take this view, and would consider it rather as an igneous rock of unknown relations to the felsites.

* Minn. Geol. Survey. Ann. Rep. 1892, p. 41.

† Amer. Jour. Science (3) XXXVII., 54. See also U. S. G. S. Bull. 109.

‡ Bull. 109, U. S. G. S.

The Kingston Group.

This group presents a series of volcanic rocks parallel to those of the Coldbrook, but far more altered. The acid members are strongly sheared, often unrecognizable as volcanic, and with a great development of secondary micas, making a quartzose or feldspathic mica-schist. Some of these schists retain their porphyritic crystals with clear cut edges and comparatively little altered, though the ground mass is all recrystallized. Ash rocks, now changed to flinty felsites, are sometimes still recognizable, but no doubt most of them are too much metamorphosed to be determined.

The basic rocks of the series are even more changed. Though mostly less cleaved, they are coarsely crystalline hornblende schists, with no traces of their original structure visible under the microscope. Remnants of the porphyritic feldspars sometimes still appear as white spots scattered through the dark schist, but their original form is lost.

These remarks apply to the New River exposures, the only ones examined by the writer. A modification of them might be necessary on study of other areas of Kingston rocks which show certainly a greater variation in the amount of metamorphism than is seen at New River.

Comparisons.

In their original character and degree of preservation the New Brunswick effusives may best be compared with those of South Mountain. The volcanics of the Boston Basin, as far as the writer has seen them, seem to be more dense and massive, less shattered and epidotized and more crystalline than ours. In field characters there is a considerable resemblance to the volcanic series along the Maine coast, at Eastport and Mount Desert; but I have seen no petrographic descriptions of these.

The rocks of the Coldbrook group seem to be much less sheared than almost all of the South Mountain rocks, to which our Coastal volcanics show a closer resemblance in this respect. The Coldbrook felsites are also of finer grain, their recrystallization not having proceeded quite as far. The characteristic structures of volcanic rocks, as has already been detailed, they possess in great perfection, the only structure of which I have not seen satisfactory examples being chain spherulites.

It is worthy of note that all these "ancient volcanic rocks," as Dr. Williams happily termed them, lie unconformably underneath Palæozoic strata. Whether they are considered as the lowest member of the Palæozoic series or the uppermost one of the pre-Cambrian rocks would seem to depend chiefly on what may be taken as the base of the Palæozoic. In New Brunswick it is rather more than elsewhere convenient to consider them as at all events pre-Cambrian, and to take the very persistent coarse grey sandstone at the base of the St. John group as the dividing line. This would leave both the volcanic series and the Etcheminian among the pre-Cambrian rocks. Nevertheless their age is probably not greatly different from the so-called Cambrian effusives lying southwest of them.

THE DYKES.

In all the rocks referred to the "Laurentian," we find a great abundance of dykes. In the later rocks they are few in number. In the volcanic series they are, naturally, not easy to recognize; a number of supposed sills are known, but of small dykes crossing the bedding of the rocks very few. The Etcheminian contains one certain dyke, and probably others. In the St. John Group one dyke is reported from near the city, but I have not seen specimens of it. Though none have been met in the Devonian slates, a few occur in the Sub-carboniferous.*

The vast majority of the dykes in Laurentian rocks, as well as the dyke and sill in the Etcheminian, are ordinary *diabase*, more or less altered and often porphyritic. With these occur several dykes which can be grouped under Prof. Rosenbusch's term of *Diorite-porphyrite*, though they border on camptonite. The Sub-Carboniferous dykes, with one or two occurring in older rocks, are *augite-porphyrite*. Some dyke rocks appearing to be of other types are known, but are all so altered as to be unrecognizable.

As a rule no general trend is to be distinguished in the direction of the diabase dykes. An exception is seen at Pleasant Point, where the granite is seamed with dykes, most of which are perfectly straight and parallel, with a north-west and, south-east direction, parallel to the great cross-fault of the Short Reach

DIORITE-PORPHYRITE. Pl. XIV. Figs. 1 and 2.

Under this name may be grouped a number of dykes varying a good deal in character, but all distinguished by a groundmass consisting of sharply idiomorphic hornblendes, lath-shaped feld-

* These notes apply merely to the neighborhood of St. John.

spars and some interstitial quartz, with phenocrysts chiefly feldspar, sometimes hornblende, occasionally quartz. They are holocrystalline, rather fine grained, and distinguishable macroscopically from diabases by their paler gray color, granular texture, and often by the short hornblende rods which stand out on weathered surfaces. The texture is mostly uniform, but in two cases is extremely irregular in different parts of the same dyke. They are singularly like the basic segregations in the granite, which latter they cut in several places, and are perhaps to be connected with it as the last member of the intruded series, injected after the rest had solidified.

Under the microscope they show numerous well formed crystals of *hornblende*, varying in size according to the width of the dyke, with prismatic faces always well developed, often also with good terminal faces. The prismatic faces are *m*, usually *b*, rarely *a*. The terminal faces are not safely determinable, but apparently *r* is present, and also a steep pyramid or clino-dome. In the less altered specimens (293, 294, 603, 608) the hornblende is brown, showing a strong pleochroism :

a—brownish-yellow.

b—brown.

c—greenish-brown.

The extinction angle is high, not less than 17°, and the colors are scarcely so deep or so red tinted as those of basaltic hornblende. It appears therefore to be a brown variety of the common kind.

Green hornblende sometimes appears as a secondary rim at the edges of the brown crystals, more commonly as a paramorph after them; all stages of the change can be seen in different crystals, the alteration beginning at the edges or in cracks. In either case the orientation of the two varieties is the same, and their extinction identical.

In the more altered dykes (90,225,284 and 336), the hornblende is entirely green, its pleochroism being

a—pale brownish yellow,

b—green,

c—bluish green.

The outlines tend to become less distinct with increasing metamorphism.

In spec. 284, from a small dyke, there are, instead of the usual corroded feldspar phenocrysts, abundant long rods of green hornblende, from 0.2 to 0.5 mm. diameter, and several millimeters in length. They are not noticeably corroded. Strictly speaking, this rock is a *camptonite*, but its real affinities seem to be with the diorite-porphyrites. Spec. 608 also shows porphyritic hornblendes, brown, like those of the groundmass, along with the feldspar phenocrysts.

Feldspar phenocrysts are present in all but one of the sections. They are much corroded and kaolinized and surrounded by a rim of clear feldspar, probably secondary, at least later than the greater part of the groundmass. When not too much altered, they can be seen to be a very basic plagioclase with extinctions up to at least 40°, indicating approximately bytownite. Twinning after the Carlsbad and Albite laws is observed, the latter polysynthetic. The crystals are strongly zonal towards the edges, the clear outer rim becoming rapidly more acid till it is an oligoclase with nearly straight extinction. The zonal outside and decayed core are not always coterminous, the latter being often more or less zonal. There is no evidence that the clear outer rim formed later than the consolidation of the rock; the decay of the feldspar within may well be due to its different composition. But it certainly formed after the greater part of the groundmass had crystallized out.

The feldspar of the groundmass is composed in part of lath-shaped crystals, with the extinction angle of labradorite, zonal at the edges like the phenocrysts, but not corroded, though often decayed at the centre. The rest of the feldspar occurs as zonal rims to the labradorite rods and as irregular grains packed in among them. It is always fresh, and judging from its extinction angles its composition varies from an acid labradorite to oligoclase or even albite.

Quartz occurs as a phenocryst in spec. 336 and shows well defined crystal outlines, somewhat corroded, not much broken up. It occurs in the groundmass of all the dykes, though never in very large amount, and is then of the same age as the clear feldspar forming the zonal rims and irregular grains, that is, the last constituent to crystalize.

Magnetite and *pyrite* occur in small, well formed crystals. *Apatite* is rare. The hornblende of the concentrates appears to show transition to an ultramarine blue variety, probably a soda-hornblende.

Flow structure is very well seen in some of these dykes, as shown in Pl. III., fig. 2.

An analysis of the diorite porphyrite, spec. 603, gave the following results:

$Si\,O_2$	48.98
$Ti\,O_2$	0.56
$Al_2\,O_3$	17.76
$Fe_2\,O_3$	2.14
$Fe\,O$	6.52
$Ca\,O$	8.36
$Mg\,O$	2.09
$Na_2\,O$	6.77
$K_2\,O$	2.08
Fixed CO_2	0.82
Loss on ignition	4.50
	100.58

I am not aware that this rock has been reported before from North America.

Diabase.

It seems very likely that this group of dykes is connected with the great surface flows underlying the Cambrian slates, and of "Huronian" age. There is a great variety in their character, the majority being normal diabase, but many having the feldspar in two or three generations, and some showing porphyritic augites.

The normal diabase has a colorless or almost colorless augite, well twinned feldspar rods and magnetite in small, irregular grains. It is usually considerably altered, the augite being either uralitized or chloritized. In about half the dykes green hornblende, uralitic or compact, has entirely replaced the augite, still retaining the outward form of the original mineral.

Some of the diabases are quite porphyritic, the plagioclase phenocrysts being short and stout, the groundmass containing small twinned rods and sometimes apparently a third generation. These appear to be more feldspathic than the rest.

Contact action has not been noticed except on the limestones. These are bleached by even small dykes for about 3 or 4 mm. from the edge; and in the case of a fifteen foot dyke near King's Mill, Fairville (spec. 63), there is a development within a few millimetres of the edge, of epidote, titanite and pale green hornblende of tremolitic habit—𝔟 and 𝔠 very pale green, 𝔞 colorless. These constituents entirely replace the lime just along the contact. The diabase itself has the usual contact character.

A single dyke (?) in the lower Coastal rocks west of the Coldbrook Marsh shows a departure from the ordinary type enough to merit special notice. It is rather coarse-grained, the magnetite in unusually large grains with a tendency towards skeletal forms. The augite is quite strongly colored, and there is a not unimportant amount of *free quartz* (See Pl. XV., Fig. 2). The microscopic description is as follows :

Augite nearly or quite as abundandant as the plagioclase, violet-brown, slightly but distinctly pleochroic, mostly moulding the feldspar, occasionally idiomorphic.

Plagioclase in large, rather short lath-shaped crystals, idiomorphic with respect to the augite, water-clear, coarsely twinned. Extinctions are about those of labradorite.

Magnetite is in unusually large grains, mostly of the peculiar skeletal forms which are sometimes referred to titaniferous iron ;* idiomorphic with respect to the feldspar and most, if not all of the augite, but with edges and angles frequently rounded.

Apatite in long slender needles varying from .05 mm. in diameter down to indeterminable minuteness; included in all other constituents, though rarely in the magnetite.

Quartz in allotriomorphic grains, moulding the feldspar and augite, forms a not unimportant constituent of the rock. It would seem to be original, judging from the unusual freshness of the rock, the size and uniformity of the quartz-grains, and the presence of apatite needles in them as abundantly as in the feldspar.

An analysis of this diabase gave the following results :

$Si O_2$	46.61
$Ti O_2$	0.55
$Al_2 O_3$	15.34
$Fe_2 O_3$	8.40
$Fe O$	8.14
$Mn O$	0.39
$Ca O$	9.27
$Mg O$	5.27
$Na_2 O$	3.04
$K_2 O$	1.41
Loss on ignition	1.41
	99.83

The presence of free quartz in so basic a rock is unusual The large size of the magnetite crystals, however, probably indicates that the early stages of cooling were slow, giving time for the basic constituents to crystallize out more completely than usual, leaving at the end a more acid residue, which was able to slightly corrode the first formed crystals of magnetite, and produced some free quartz on crystallization. The same phenomenon is seen in the diorite-porphyrite.

* The analysis, however, fails to show any considerable amount of titanic acid.

AUGITE-PORPHYRITE.

The dykes in Sub-carboniferous sandstone at Poverty Hall Point appear to be of this rock. The phenocrysts are chiefly augite, the larger ones being entirely, the smaller ones frequently chloritized. They present the usual short stout crystals characteristic of augite, and are quite abundant. Augite occurs also in the groundmass, but is mostly destroyed. *Magnetite* is abundant in small crystals. *Olivine* phenocrysts occur rarely. The *plagioclase* is confined to the groundmass and is in small lath shaped crystals. A micaceous mineral occurring in small plates in the groundmass is perhaps an altered biotite, and is quite abundant.

With these Carboniferous dykes may be placed from lithological resemblance spec. 148, a dyke in the volcanic series at Lily Lake, known as labradorite-porphyrite. It contains large phenocrysts of completely altered feldspar. Spec. 251 is perhaps also related, showing augite and occasional feldspar phenocrysts and a much altered groundmass which contains a great abundance of plates of altered biotite (?) in a feldspathic base now apparently recrystallized and granular.

ADDITIONAL NOTES ON THE LAURENTIAN ROCKS.

Some further notes may be made as to the Laurentian areas in a few places otside of the district studied last year; though no general examination was made of them.

A more massive gneiss than has yet been noticed occurs beyond Sutton Station, on the Canadian Pacific Railway; it is strongly feldspathic, banded, and contains a bed of limestone.

The intrusive granites occur both east and west of the mapped district. To the southwest are also large masses of granite of a different type, non-porphyritic, much altered, and perhaps older than the Indiantown granite. At Musquash the contact is exposed between it and the Devono-Silurian limestone. The granite is here clearly seen to be the older rock.

The gabbro (olivine-norite) hill north of Dolin's Lake presents less variation in feldspar contents than the small Indiantown exposure. Its grain varies greatly, crystals being sometimes 2″ across, sometimes finely granular and almost ophitic (Pl. XV., Fig. 1), as in spec. 474. This section fails to show olivine; it is made up of colorless augite, weakly pleochroic hypersthene, biotite, and basic plagioclase, the latter giving a maximum extinction of about 36°, and occurring in more or less lath-shaped crystals, which however do not distinctly appear to be older than the bisilicates, and are certainly in part younger. The biotite is later than much of the feldspar. Magnetite and apatite occur scatteringly. This phase of the norite appears to occur as a heavy dyke or intrusive knob in the main mass.

The relations of the norite to the surrounding rocks could not be determined. It is cut by three sets of dykes.

1. Eurite and granite-veins, probably connected with the granite.

2. Diabase.

3. Augite-porphyrite, older than the diabase, and very much decayed.

OTHER VOLCANIC ROCKS IN NEW BRUNSWICK.

The foregoing article deals with but a small part of the volcanic rocks of New Brunswick. Besides the extension of the Coldbrook and Kingston groups to the northeast and southwest, and other detached areas lying further inland, there is a great body of pre-Cambrian rocks, chiefly volcanic, in the northern part of the Province, forming a considerable part of the broken and unsettled country about the headwaters of the Tobique, Nepisiquit and Northwest Miramichi rivers. In several of the later formations, also, great quantities of volcanic material occur, notably in the Silurian of Passamaquoddy Bay, at the base of the Devonian around the shores of Baie Chaleur, in the Sub-carboniferous at the Blue Mountains near the Tobique River, and around the head of Grand Lake, and in the Triassic at Quaco and Grand Manan Island. No petrographic study of any of these rocks has yet been made, and they afford a fruitful field for future investigation. The great areas of Devonian granites extending across the centre of the Province from the southwest nearly to the northeast boundary would also well repay study, especially with regard to their well marked contact phenomena.

SUMMARY.

The Huronian in Southern New Brunswick is in large part made up of surface volcanic rocks. The lower part or Coldbrook group is almost exclusively volcanic; the upper part or Etcheminian is clastic, while the intermediate Coastal contains both volcanic and sedimentary members. The effusive rocks include lavas, breccias and tuffs, and with them may be placed a holocrystalline soda-granite which is probably either an intrusion or a very thick surface flow.

The rock types represented may be conveniently divided into acid and basic, the intermediate varieties being little developed. The acid rocks are more abundant. They are chiefly felsite-porphyry and show all the characteristic structures of surface

flows. Vesicles, flow-lines and flow-breccia are very common, and the scattered phenocrysts are often broken and displaced. Spherulitic and perlitic structures, trichites and skeleton crystals are sometimes excellently preserved. The basic rocks are chiefly diabase, and are in part as late as the Etcheminian. Breccias and tuffs are very abundant. The alteration is not excessive except in the tuffs, many of which are now unrecognizable. The massive rocks are completely devitrified but otherwise not much changed; schistose cleavage is marked in the more highly metamorphic areas, but is generally absent.

The soda-granite is a quartz-anorthoclase rock with augite and hornblende as the dark silicates. It shows a very strong granophyric structure in the central part, but is finer grained and somewhat porphyritic towards the edges.

The dyke rocks are all basic and predominantly diabase; but a number belong to the rare type of diorite-porphyrite. The latter is a panidiomorphic rock with feldspar, brown hornblende and subordinate quartz. The age of the dykes is probably pre-Cambrian,* excepting a few of different type from the rest.

In concluding, I wish to express my acknowledgments to Prof. J. F. Kemp, for his assistance and advice in carrying out this study. I am also much indebted to my father, Mr. G. F. Matthew, especially as regards the details of local geology.†

* And hence any rocks that they cut would be still earlier. They are very abundant in the intrusive granites near the city, and chiefly on this account the age of the granite was provisionally placed as pre-Cambrian. It seems well to make this point clear, as it has been mis-stated in a recent abstract of the article describing the granites.

† Geological Department, Columbia College, April, 1895.

PLATE XII.

FIG. 1. *Spherulitic structure* in red felsite-porphyry (apobsidian) from the Hammond River below Upham, N. B. This section shows under higher magnification well preserved trichites throughout both the spherulitic and non-spherulitic parts of the rock (See Fig. 1, p 199). Spec. 664. Magnified 37 diameters.

FIG. 2. *Red felsite-porphyry* (trachyte), showing feldspar in three generations; large phenocrysts, small rod-like crystals and small grains not well bounded. The glassy material has been changed to micro-felsite. The only other minerals are magnetite and secondary limonite replacing in part one of the orthoclase phenocrysts. Spec. 575. × 12 diam.

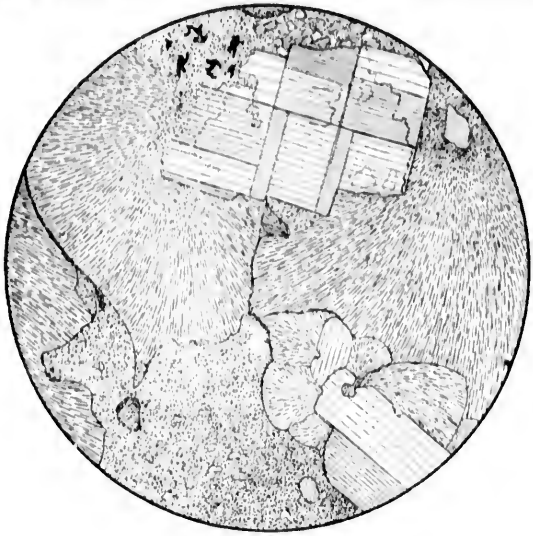

FIG. 1.

FIG. 2.

PLATE XIII.

FIG. 1. *Perlitic structure* in red felsite-porphyry (apobsidian) from Hammond River below Upham. The stippled part is microfelsite, which shows a flow-brecciated structure, the horizontal shading represents secondary quartz and feldspar. The perlitic cracks are in fact preserved in a brightly polarizing substance, but this was not easy to represent in the drawing. × 67 diam.

FIG. 2. *Skeleton crystals of magnetite* in black felsite porphyry (petrosilex) from Hanford Brook. Spec. 570. × 67 diam.

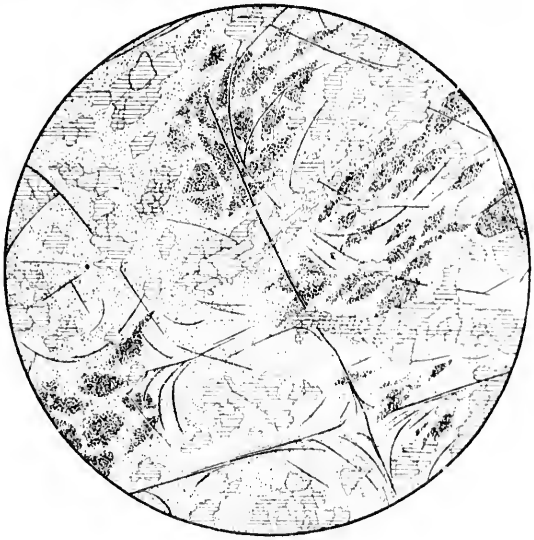

Fig. 1.

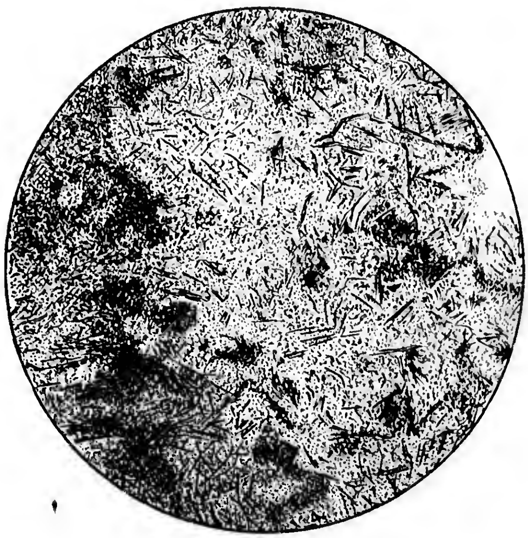

Fig. 2.

PLATE XIV.

FIG. 1. *Diorite-porphyrite*, coarse grained. The hornblende is represented by heavy shading; the feldspar is lightly shaded. An attempt is also made to represent the zonal structure and decayed cores of the phenocrysts. The quartz is unshaded and the magnetite is dead black. Spec. 608. × 37 diam.

FIG. 2. *Diorite-porphyrite*, fine-grained. The shading is the same as in Fig. 1; it shows in addition a well marked flow-structure, and quartz as phenocryst; the quartz in the groundmass is not represented, nor are the feldspar individuals distinguished. × 30 diam.

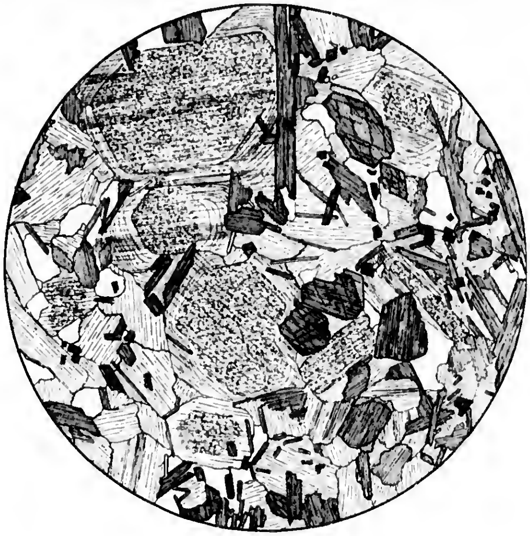

FIG. 1.

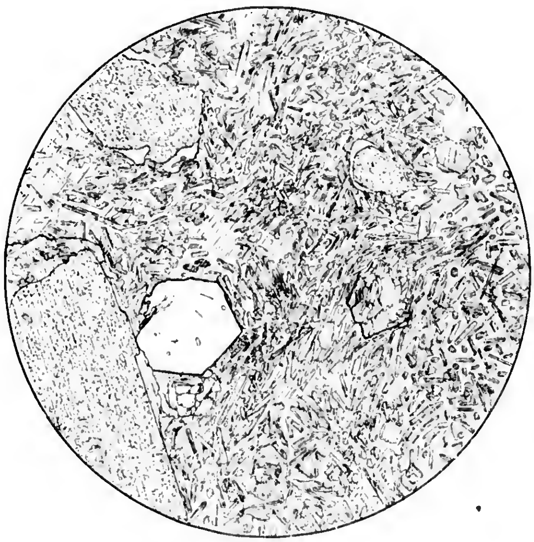

FIG. 2.

PLATE XV

FIG. 1. *Fine-grained Norite.* A phase of the olivine-gabbro at Dolin's Lake. Biotite is represented by heavy parallel lines, plagioclase by light ones: augite and hypersthene by irregular cracks, the hypersthene sometimes showing schillerization with innumerable minute parallel rods of magnetite. Spec. 173. × 77 diam.

FIG. 2. *Quartz-bearing diabase* from west of the Coldbrook Marsh. The feldspar is shaded with parallel lines, the augite by irregular ones, the magnetite being black and the quartz unshaded. The abundant apatite needles are too small to be shown in the figure. Spec. 301. × 20 diam.

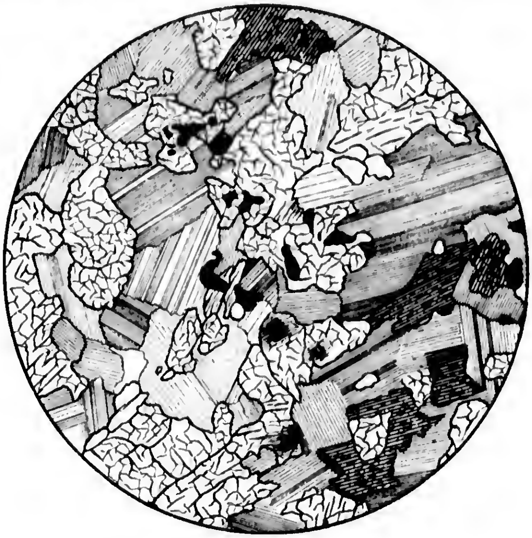

Fig. 1.

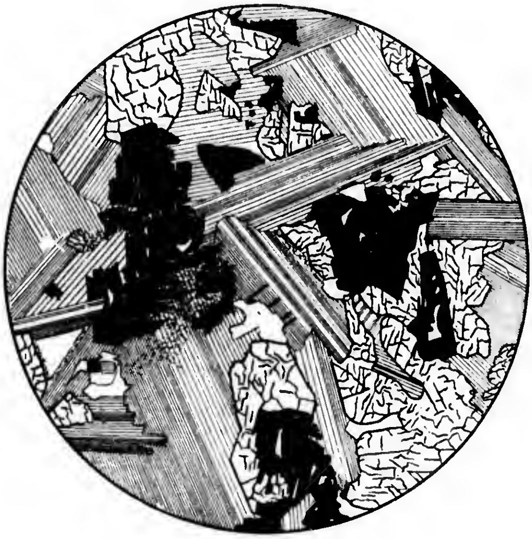

Fig. 2.

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PLATE XVI.

FIG. 1. *Soda-granite*, from Titus' Mill. The feldspar is stippled, the fine twinning of the anorthoclase, being represented where visible by parallel lines. Some attempt is made to show the comparative alteration of the feldspar by the heaviness of the stippling. Hornblende is represented by diagonally crossing parallel lines. Quartz is unshaded and magnetite is dead black. Spec. 661. × 18 diam.

FIG. 2. *Soda-granite* fine grained and porphyritic. From the Hammond River below Upham. Shading as in the last figure, but augite is represented by irregular lines. Spec. 666. × 37 diam.

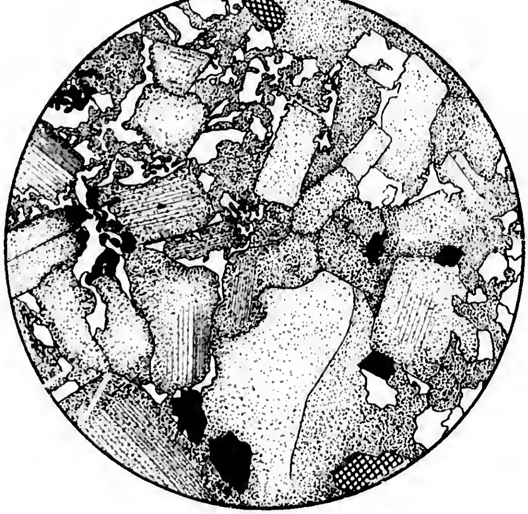

FIG. 1.

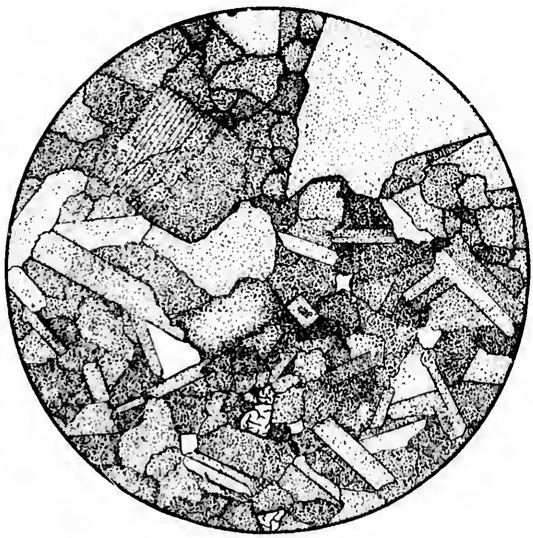

FIG. 2.

PLATE XVII.

FIG. 1. *Granophyric structure* in soda-granite from near Hardingville. The feldspar is represented by parallel horizontal lines; the quartz is unshaded; the hornblende is represented by diagonally crossing lines, zircon by irregular heavy cracks, and chlorite by arrow points. In the upper left hand quadrant the quartz is mostly in minute trigonal prisms variously shown by different sections. In the upper right hand quadrant the quartz is regular and minute at the centre, but becomes coarse and irregular outside. In the lower half the quartz is seen radiating out from a crystal of feldspar, becoming coarser and more irregular as it continues its growth. The feldspar between these quartz growths is in part optically continuous with the central crystal. From Spec. 656. × 80 diam.

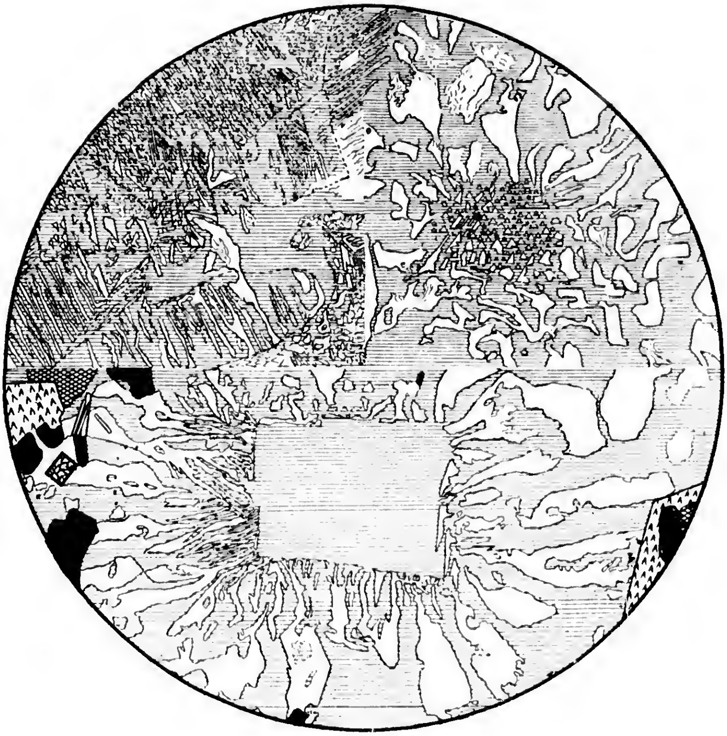

FIG. 1.

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