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NOTES ON GRANITIC ROCKS.

By T. STERRY HUNT, LL.D., F.R.S.*

FIRST AND SECOND PARTS.

Read before the American Association for the Advancement of Science at Troy, August 20, 1870.

Contents of Sections.—§ 1-2, Definitions of granite and syenite; § 3 Structure of granitic and gneissic rocks; § 4-5, Felsites and felsite-porphyrries; § 6, Gneisses and granites of New England; § 7, Granitic dykes and granitic vein-stones; § 8, Scheerer's theory of granitic veins; § 9-10, Elie de Beaumont on granites and granitic emanations; § 11, Granitic distinguished from concretionary veins; § 12, Von Cotta on granitic veins; § 13-14, The author's views on the concretionary origin of granitic veins; § 15, The banded structure of granitic veins; § 16, Granitic veins of Maine, Brunswick; § 17, Topsham, Paris; § 18, Westbrook, Lewiston; crystalline limestones; § 19, Danville, Ketchum; § 20, Demuded granitic masses; § 21, Banded veins; Biddeford, Sherbrooke; § 22, Veins at various New England localities; § 23, Mineral species of these veins; § 24, Veins in erupted granites; § 25, Geodes in granites; § 26, Veins distinguished from dykes; § 27, Volger and Fournet on the origin of veins; § 28, 29, Certain fissures and geodes distinguished from veins opening to the surface; § 30, 31, Temperatures of crystallization of granitic minerals.

§ 1. The name of granite is employed to designate a supposed eruptive or exotic unstratified composite rock, granular, crystalline in texture, and consisting essentially of orthoclase-feldspar and quartz, with an admixture of mica, and frequently of a triclinic feldspar, either oligoclase or albite. This is the definition of granite given by most writers on lithology, and applies to a great portion of what are commonly called granitic rocks; there are, however, crystalline granite-like aggregates in which the mica is replaced by a dark colored hornblende or amphibole, and to such a compound rock many authors have given the name of syenite, while to those in which mica and hornblende co-exist, the name of syenitic granite is applied. It is observed that in certain of these hornblende granites the quartz becomes less in amount than in ordinary granites, and finally disappears altogether, giving rise to a rock composed of orthoclase and hornblende only. To this

* From the American Journal of Science for February and March, 1871.
binary aggregate von Cotta and Zirkel would restrict the term syenite, which was already defined by d'Omalius d'Halloy to be a crystalline aggregate of hornblende and feldspar, by which orthoclase-feldspar may be understood, since he describes varieties of syenite, as passing into diorite; a name by most modern lithologists restricted to a compound of albite or some more basic triclinic feldspar with hornblende. It is apparently by failing to appreciate the distinction between orthoclase and triclinic feldspars, in this connection, that Haughton has lately described under the name of syenite rocks composed of crystalline labradorite and hornblende.

§ 2. Naumann, regarding orthoclase and quartz as the essential constituents of granite, designates those aggregates which contain mica as mica-granites, and thus distinguishes them from hornblende-granites, in which the mica is replaced by hornblende. These definitions seem the more desirable as the name of granite is popularly applied both to the hornblende and the micaeous aggregates of orthoclase and quartz. There are not wanting examples of well-defined rocks of this kind in which both mica and hornblende are almost or altogether wanting. Such rocks have been designated binary granites, a term which it will be well to retain. Chlorite and talcose granites, into the composition of which chlorite and talc enter, need only be mentioned in this connection. The name of syenite, so often given to hornblende granites, will, in accordance with the views already expressed, be restricted to rocks destitute of quartz. While the disappearance of this mineral from hornblende granites is held to give rise to a true syenite, the same process with micaeous granites affords a quartzless rock consisting of orthoclase and mica, for which we have no name. Great masses of an eruptive rock, granite-like in structure, and consisting of crystalline orthoclase or sanidin, without any quartz, occur in the province of Quebec. This rock contains in some cases a small admixture of black mica, and in others an equally small proportion of black hornblende. The latter variety might be described as syenite, but for the former we have no distinctive name, and I have described both of these by the name of granitoid trachytes, a term which I adopted the more willingly on account of the peculiar composition of the feldspar; and also because compact and finely granular rocks in the same region, having a similar chemical composition, present all the characters of typical trachytes, and apparently graduate into the
granitoid rocks just noticed.* In all attempts to define and
classify compound rocks, it should be borne in mind that they are
not definite lithological species, but admixtures of two or more
mineralogical species, and can only be arbitrarily defined and
limited.

§ 3. Having thus defined the mineral composition of granitic
rocks, we proceed to notice their structure. Gneiss has the same
mineral elements as granite, but is distinguished by the more or
less stratified and parallel arrangement of its constituents, and
lithologists are aware that in certain varieties of gneiss, this
structure is scarcely evident, except on a large scale, so that the
distinction between gneiss and granite rests rather on geognostic
than on lithological grounds. To the lithologist, in fact, the
granitoid gneisses are simply more or less stratiform granites, while
it belongs to the geologist to consider whether this structure has
resulted from a sedimentary deposition, or from the flowing of a
semi-fluid heterogeneous mass giving rise to a stratiform
arrangement.

§ 4. The rocks having the mineralogical composition of
granites present a gradual passage from the coarse structure of
ordinary micaeous, hornblende, and binary granites to finely
granular and even impalpable mixtures of the constituent minerals,
constituting the rocks known as felsite, urite and petrosiex. These
rocks are often porphyritic from the presence of crystals of
orthoclase, and sometimes of crystals or grains of quartz imbedded
in the finely granular or impalpable paste. These felsites and
felsite-porphyries are, in very many cases at least, stratified or
indigenous rocks, and they are sometimes found associated with
granular aggregates of different degrees of coarseness, which show
a transition from true felsites into granitic gneisses. The resemblances
in ultimate composition between felsites, granites and
granitic gneisses are so close that it cannot be doubted that their
differences are only structural.

§ 5. Felsites and felsite-porphyries are well known in eastern
Massachusetts, at Lynn, Saugus, Marblehead and Newburyport,
and may be traced from Machias and Eastport in Maine, along
the southern coast of New Brunswick to the head of the Bay of
Fundy, with great uniformity of type, though in every place subject

* Amer. Journal of Science, II, xxxvii, 95. See also Zirkel, Petro-
graphie, ii, 179.
to considerable variations, from a compact jasper-like rock to more or less coarsely granular varieties, all of which are often porphyritic from feldspar crystals, and sometimes include grains or crystals of quartz. The colors of these rocks are generally some shade of red, varying from flesh-red to purple; pale yellow, gray, greenish and even black varieties are however occasionally met with. These rocks are throughout this region distinctly stratified, and are closely associated with dioritic, chloritic and epidotic strata. They apparently belong, like these, to the great Huronian system.

§ 6. Many of the so-called granites of New England are true gneisses, as for example, those quarried in Augusta, Hallowell, Brunswick, and many other places in Maine, which are indigenous rocks interstratified with the micaceous and hornblende schists of the great White Mountain series. To this class also, judging from lithological characters, belong the so-called granites of Concord and Fitzwilliam, New Hampshire. These indigenous rocks are tenderer, less coherent, and generally finer grained than the eruptive granites, of which we have examples in the micaceous granite of Biddeford, Maine, and the hornblende granites of Marblehead and Stoneham, Mass., and Newport, Rhode Island, in all of which localities the contact of the eruptive mass with the enclosing rock is plainly seen, as is also the case farther eastward, on the St. Croix and St. John's Rivers, in New Brunswick, and in the Cobequid Hills and elsewhere in Nova Scotia. The hornblende granites of Gloucester, Salem and Quincy, Massachusetts, seem also, from their lithological characters, to belong to the class of exotic or true eruptive granites.* The farther discussion of the nature and origin of these gneisses and granites is reserved for another occasion, and we now proceed to notice the history of granitic veins.

§ 7. The eruptive granitic masses just noticed, not only include fragments of the adjacent rocks, especially near the line of contact, but very often send off dykes or veins into the surrounding strata. The relation of these with the parent mass is however generally obvious, and it may be seen that they do not differ from it except in being often finer grained. These injected or intruded veins are not to be confounded with a third class of granitic aggregates, which I have elsewhere described as granitic veinstones, or, to

express their supposed mode of formation, endogenous granites. They are to the gneisses and mica-schists, in which they are generally enclosed, what calcite veins are to stratified limestones, and although long known, and objects of interest from their mineral contents, have generally been confounded with intrusive granites.

§ 8. Scheerer, in his famous essay on granitic rocks, which appeared in the Bulletin of the Geological Society of France in 1847, (vol. iv, p. 468), conceives the congealing granitic rocks to have been impregnated with "a juice" which was nothing else than a highly heated aqueous solution of certain mineral matters. This, under great pressure, oozed out, penetrating even the stratified rocks in contact with the granite, filling cavities and fissures in the latter, and depositing therein crystals of quartz and of hornblende, the arrangement of which shows them to have been of successive growth. Neither Scheerer nor Virlet d'Aont, who supported his views, however (ibid., iv. p. 493) extended them to feldspatic veins, though Daubrée, at an earlier date, had described certain granitic veins in Scandinavia as having been formed by secretion, rather than by igneous injection as maintained by Durocher.

§ 9. Elie de Beaumont, starting from the hypothesis of a cooling liquid globe, imagined "a bath of molten matter on the surface of which the first granites crystallized." From the ruins of these were formed the first sedimentary deposits, but directly beneath were other granitic masses, which became fixed immediately afterward. "Some parts of these masses, coagulated from the commencement of the cooling process, but not completely solidified, were then erupted through the sedimentary deposits" just mentioned. "In these jets of pasty matter" were contained many of the rarer elements of the granitic magma, which were thus concentrated in the outermost portions of the granitic crust, and in the ramifications formed by these portions in the masses through which they were forced by the eruptive agents. Those portions of the granitic masses and their ramifications in which these rarer elements are concentrated, are distinguished from the rest of the masses alike by their exterior position and their peculiar structure. They are often coarse-grained, and include the pegmatites, tourmaline-granites, and veins carrying cassiterite and columbite often abounding in quartz. These mineral products are to be regarded as emanations from the granite, and are described as a granitic aura, constituting what Humboldt has call-
ed the penumbra of the granite. (Bull. Soc. Geol. de France, (2) iv, 1249. See particularly pages 1295, 1321 and 1323).

§ 10. While Fournet, Durocher and Rivière conceived the granitic magma to have been purely anhydrous, and in a state of simple igneous fusion, Elie de Beaumont maintained with Poulett-Serope and Scheerer that water had in all cases intervened, and that a few hundredths of water might, at a low red heat, have given rise to the condition of imperfect liquidity which he imagined for the material of the injected granites. The coarsely crystalline granitic veins were, according to him, veins of injection, and he speaks of them as examples in which "the phenomena essential to the formation of granite had been manifested with the greatest intensity." The granitic emanations, which are supposed to have furnished the material of these veins, appear to be regarded by him as the result of a process of eliquation from the congealing granitic mass. De Beaumont is careful to distinguish between them and those emanations which are dissolved in mineral waters, or are exhaled as volcanic vapors (page 1324). To the agency of such waters he ascribes the formation of concretionary veins, which are generally characterized by their symmetrically banded structure. He further adds that granites, as to their mode of formation, offer a character intermediate between ordinary veins and volcanic and basic rocks. This is conceivable as regards granitic veins, since these, according to him, although formed by injection, and not by concretion, result from a process of emanation from the parent granitic mass, which may be described as a kind of segregation.

I have thus endeavored to give, for the most part in his own words, the views on the origin of granites enunciated by the great French geologist in his classic essay on Volcanic and Metalliferous Emanations, published in 1847. They belong to the history of our subject, and are remarkable as a clear and complete expression of those modified plutonic views which are probably held by a great number of enlightened geologists at the present time. My reason for dissenting from them, and the theories which I offer in their stead will be shown in the sequel.

§ 11. Elie de Beaumont, while regarding the formation of granitic veins as a process in which water intervened to give fluidity to the magma, was careful to distinguish the process from that of the production of concretionary veins from aqueous solution, and supposed the fissures to have been filled by the injection of a
jet of pasty matter derived from a consolidating granitic mass. Daubrée and Scheerer, in describing the granitic veins of Scandinavia, conceive the material filling them to have been derived from the enclosing crystalline strata instead of an unstratified granitic nucleus, but do not, so far as I am aware, compare their formation to that of concretionary veins. Their publications on this subject, it should be said, are both anterior to the essay of de Beaumont.

§ 12. The notion that all granitic veins are the result of some process of injection, and not to be confounded with concretionary veins, seems indeed to have been general up to the present time. Even von Cotta, while strongly maintaining the aqueous and concretionary origin of metalliferous veins in general, when describing those consisting of quartz, mica, feldspar, tourmaline, garnet, and apatite, with cassiterite, wolfram, etc., which occur at Zinnwald and at Johanngeorgenstadt, is at a loss whether to regard these veins, from their granitic character, as igneous-fluid injections or as concretionary lodes. In support of the latter view he refers to their more or less regular and symmetrically banded structure, and while recalling the fact that mica and feldspar may both be formed in the humid way, considers the nature of these veins to be very problematical, and the question of their origin a difficult one.—(Ore Deposits, Prime's translation, 1870, pages 110—124).

§ 13. I have for several years taught that granitic veins of the kind just referred to are concretionary and of aqueous origin. In 1863 I described certain veins in the crystalline schists of the Appalachian region of Canada, "where flesh-red orthoclase occurs so intermingled with chlorite and white quartz as to show the contemporaneous formation of the three species. The orthoclase generally predominates, often reposing upon or surrounded by chlorite; at other times it is imbedded in quartz, which covers the latter. Drusy cavities are also lined with small crystals of the feldspar, and have been subsequently filled with cleavable bitter-spar, sometimes associated with specular iron, rutile and sulphuretted copper ores." A study of these veins shows a transition from those "containing quartz and bitter-spar with a little chlorite or talc, through others in which feldspar gradually predominates, until we arrive at veins made up of orthoclase and quartz, sometimes including mica, and having the character of a coarse granite; the occasional presence of sulphurets of copper and specular iron characterizing all of them alike. It is probable
that these, and indeed a great proportion of quartzo-feldspatic veins are of aqueous origin, and have been deposited from solutions in fissures of the strata, precisely like metalliferous lodes. This remark applies especially to those granitic veins which include minerals containing the rarer elements. Among these are boron, phosphorus, fluorine, lithium, rubidium, glucinum, zirconium, caesium, tin and columbium; which characterize the mineral species apatite, tourmaline, lepidolite, spodumene, beryl, zircon, allanite, cassiterite, columbite, and many others."—(Geology of Canada, p. 476, also p. 644.)

In this connection I referred to the occurrence of orthoclase with quartz, calcite, zeolites, epidote and native copper in certain mineral veins of Lake Superior, so well described by Prof. J. D. Whitney. (American Journal of Science, II, xxviii, 16). The associations, according to him, show the contemporaneous crystallization of the copper, natrolite, calcite and feldspar, which last was found by analysis to be a pure potash-orthoclase.

§ 14. In 1864, this view was still farther insisted upon in the Amer. Journal of Science (II, xxxvii, 252), where, in speaking of mineral veinstones "which doubtless have been deposited from aqueous solution," it is added, "while their peculiar arrangement, with the predominance of quartz and non-silicated species, generally serves to distinguish the contents of these veins from those of injected plutonic rocks, there are not wanting cases in which the predominance of feldspar and mica gives rise to aggregates which have a certain resemblance to dykes of intrusive granite. From these, however, true veins are generally distinguished by the presence of minerals containing boron, fluorine, phosphorus, caesium, rubidium, lithium, glucinum, zirconium, tin, columbium, etc.; elements which are rare, or found only in minute quantities in the great mass of sediments, but are here accumulated by deposition from waters, which have removed these elements from the sedimentary rocks and deposited them subsequently in fissures."

In the Report of the Geological Survey of Canada for 1865 (p. 192), I have, in describing the veins of the Laurentian rocks, insisted still farther on the distinction just drawn between granitic dykes and granitic veinstones, which latter I have proposed to call endogenous rocks, to indicate the mode of their formation, and to distinguish them from intrusive or exotic rocks, and sedimentary or indigenous rocks.

§ 15. The peculiar banded arrangement, which is so charac-
teristic in concretionary veins not granitic in composition, is probably not less marked in granitic veinstones, and often appears in these in a remarkable manner, showing that they have been formed by successive depositions of mineral matter, and generally in open fissures. This structure, and various peculiarities to be observed in granitic veinstones, will be best illustrated by descriptions of various localities, most of which I have personally examined. It is proposed to notice first, the veins of the gneiss and mica-schist series of New England, and secondly those of the Laurentian rocks of New York and Canada. In the latter class will be noticed the more or less calcareous veinstones into which the Laurentian granitic veins are found to graduate.

§ 16. It is in the series of micaeous schists with interstratified gneisses (§ 6) which I have elsewhere provisionally designated the Terranovan series,* that I have seen concretionary granitic veins in the greatest abundance and on the grandest scale. This stratified system, which is well seen in the White Mountains, appears to extend southward to Long Island Sound and northeastward beyond the limits of Maine. It is in this state that I have particularly studied the granitic veinstones of this system, whose history may be illustrated by a few examples from notes taken on the spot. In Brunswick the strata near the town are fine-grained, friable, dark colored, micaeous and hornblendic, passing into mica-schist on the one hand, and into well-marked gneiss on the other, and dipping to the S. E. at angles of from 15° to 40°. Very similar beds are found in the adjoining town of Topsham, and in both places they include numerous endogenous granitic veins. The course of these is generally N. W., or at right angles to the strike, though occasionally for short distances with the strike, and intercalated between the beds; the veins vary in breadth from a few inches to sixty feet, and even more. They generally consist in great part of orthoclase and quartz, with some mica and tourmaline, and offer in the associations and grouping of these minerals many peculiarities, which are met with not only in different veins but in different parts of the same vein. In

*Amer. Journal of Science for July, 1870, page 83, and Can. Naturalist, V. p. 193.—The rocks of this White-Mountain series are in the present state of our knowledge supposed to be newer than the Huronian system noticed in § 5, to which, with Macfarlane and Credner, I refer the crystalline schists, with associated serpentines and diorites, of the Green Mountains.
some cases, colorless vitreous quartz predominates greatly, and en-
closes crystals of milk-white orthoclase, often modified, and from
one to several inches in diameter. At other times pure vitreous
quartz forms one or both walls, or the center of the vein, or else is
arranged in bands parallel with the sides of the vein, and some-
times a foot or more in thickness, alternating with similar bands
consisting wholly or in great part of orthoclase, or of an admixture
of this mineral with quartz, having the peculiar structure of what
is called graphic granite, or else presenting a finely granitoid
mixture of the two minerals, with little or no mica, and with small
crystals of deep red garnet. Prisms of black tourmaline are also
met with in these veins, and more rarely beryl and even chryso-
beryl. In the rock-cutting on the Lewiston railroad, just below
Topsham bridge over the Androscoggin, there is a fine exhibition
of these veins, which present alternate coarser and finer grained
layers, traversed by long spear-shaped crystals of dark mica pass-
ing from one layer to another.

§ 17. A remarkable example of a vein of considerable dimen-
sions is seen in the feldspar-quarry in Topsham, which occurs in a
dark fine-grained friable micaceous schist. At the time of my
visit, in 1869, the limits of the vein were not seen, though large
quantities of white orthoclase and of vitreous quartz had already
been extracted. These were each nearly pure, and in alternate
bands, the quartz presenting drusy cavities lined with remarkable
tabular crystals. One band was made up in great part of large
crystals of mica, and portions of the vein consisted of a granular
saccharoidal feldspar. The famous locality of red, green and blue
tourmalines, with beryl, lepidolite, amblygonite, cassiterite, etc.,
at Mount Mica in Paris, is a huge granitic vein, which, with many
others, is included in a dark colored very micaceous gneiss.

§ 18. In Westbrook numerous small veins of this kind, holding
coarsely lamellar orthoclase with black tourmaline and red garnet,
intersect strata of fine-grained whitish granitoid gneiss. In Wind-
ham the dark colored staurolite-bearing mica-schist of this series
is traversed by a granitic vein holding crystals of beryl. In Lewiston
a large vein of coarse graphitic granite, holding black
tourmaline, and showing fine-grained bands, cuts a great mass of
bluish gneissoid limestone, which forms an escarpment near the
railroad, about half a mile below the town. This limestone, which
dips eastward about 15°, is interlaminated with thin quartzite
beds, which are seen on weathered surfaces to be much contorted.
The bluish crystalline limestone is mixed with grains of greenish pyroxene, and includes nodular granite masses of white crystalline orthoclase with quartz, enclosing large plates of graphite, crystals of hornblende, and more rarely of apatite. These associations of minerals are met with in the granitic veins of the Laurentian limestones, to be noticed elsewhere. The limestone of Lewiston, however, appears to be included in the great mica-schist series of the region; where similar beds, though less in extent, are met with in various places, sometimes associated with pyroxene, garnet, idocrase and sapphire. A thin band of impure pyroxenic limestone, like that of Lewiston, occurs with the mica-schists on the Maine Central Railroad, near Danville Junction, and beds of a purer crystalline limestone were formerly quarried in the south-east part of Brunswick, where they are interstratified with thin-bedded dark hornblende and micaaceous gneiss, dipping S. E. at a high angle.

§ 19. At Danville Junction strata of hornblende and micaaceous gneiss, passing into mica-schists, dip S. E. at moderate angles, and include huge veins of endogenous granite. Two of these appear in the hill just south of the railroad station, apparently running with the strike of the beds. They are seen to rest upon the mica-schist, and in one of them a mass of this rock, three feet in width, is enclosed like a tongue in the granite, which has a transverse breadth of about seventy-five feet. Notwithstanding the apparent intercalation of these granite masses the proof of their foreign origin is evident in a transverse fracture and slight vertical dislocation of the mica-schist, around the broken edges of which the granite is seen to wrap. The endogenous character of this granite is well shown by its banded structure; belts of white quartz some inches wide alternate with others of coarsely cleavable orthoclase, while other portions hold black tourmalines and garnets of considerable size.

The evidence of disturbance of the strata in connection with these endogenous granites is seen on a large scale at the falls of the Sunday River in Ketchum. There, mica-schists and gneisses, similar to those already noticed, enclose great masses of endogenous granite, which are seen to be transverse to the strata. On one side of such a mass more than sixty feet wide, the schistose strata are twisted from their regular N. E. strike to the N. W., and so enclosed in the granite as to appear as if interstratified with it for short distances. The banded structure of the transverse granite veins is here very marked. Some portions present
cleavage-planes of orthoclase six inches in diameter; other parts, which are less coarse, abound in mica. Similar banded granite veins abound in the adjoining towns of Newry and North Bethel, and sometimes present layers of quartz six inches or more in thickness, besides large crystals of mica, and more rarely apatite. These veins are often irregular in shape and bulging at intervals, and they sometimes run partially across the beds, which seem to have been distended and disturbed, a fact which was also observed in the thin-bedded schists in contact with some of the veins in Brunswick, and is apparently due to the expansive force of crystallization, as noticed in § 27.

§ 20. The locality already described at Danville offers an instructive example of a phenomenon often met with in the region now under consideration, where granitic masses, resisting the actions which have degraded the soft enclosing schists, stand out in relief on the surface, and seem to constitute the rock of the country. A careful search will however show that they are simply veins or endogenous masses of very limited dimensions, rising from out of the mica-schists, which are often concealed by the soil. This is well seen about the lower falls of the Presumpscott near Portland, where the mica-schists with some fine-grained gneisses, dipping S. E. at angles of from 30° to 40°, enclose large numbers of granitic veins, which, though sometimes but a few inches in breadth, often measure twenty or even fifty feet, and are usually very coarse-grained, with white mica, black tourmaline, and more rarely beryl. They are sometimes transverse to the stratification, but more often parallel, and, rising above the soil, are very conspicuous.

§ 21. We have already noticed the exotic granites of Biddeford, which are intruded among fine-grained bluish or grayish silicious strata. These latter are traversed by numerous veins of endogenous granite, which are very unlike in aspect to the intrusive rock. One of these veins near Saco Pool, has a diameter of about an inch and a half, and presents on either wall a layer of yellowish crystalline feldspar about one fourth of an inch in thickness, which includes long plates of dark brown mica. These penetrate the central portion of the vein, which is a broadly crystalline bluish orthoclase, enclosing small portions of quartz after the manner of a graphic granite. The yellowish and less coarsely crystalline feldspar with its accompanying mica, had evidently lined the walls of the vein while the centre yet remained open, and
had moreover entirely filled a small lateral branch. The same conditions are seen in the filling of other veins in this vicinity, which are often much larger, and present upon their walls bands of an inch or two of the yellowish feldspar with mica.

The successive filling of a granitic vein is still more clearly shown in a specimen from Sherbrooke, Nova Scotia, which I owe to the kindness of Prof. H. Y. Hind. The vein, which is seen to be transverse to the adherent fine-grained mica-schist, has a breadth of nearly four inches, about two-thirds of which is symmetrical, and is included between two layers, perpendicular to the walls, consisting of a fine-grained mixture of white feldspar and quartz, each about one-fourth of an inch thick, and marked by subordinate zones, more or less quartzose. Within these two bands is a coarser aggregate, consisting of two feldspars, with some quartz and muscovite, plates of which, and crystals of pink orthoclase penetrate an irregular layer of smoky quartz varying from one-eighth to one-half an inch in diameter. This fills the center of the symmetrical portion of the vein, on one side of which is the mica-schist, while the other is bounded by a band of more than half an inch of fine-grained granite with yellowish-green mica, presenting large crystals of feldspar near the outer margin, where it is succeeded by a layer of pure smoky vitreous quartz of about the same thickness, whose outer surface, against the wall, shows irregular bosses or nodular masses, the depressions between which are occupied by a finely granular micaeous aggregate unlike any other part of the vein in texture. This description may be read in connection with the remarks in § 27.

Dana has described and figured a similar granitic vein, banded with quartz, observed by him at Valparaiso in Chili, (Manual of Geology, 1862, p. 713); and has moreover maintained that such granitic veins, like ordinary metalliferous lodes, are clearly concretionary in their origin, and have been filled by slow and successive deposits from aqueous solutions. His testimony to the views which I have advocated in this paper had been overlooked by me, or it would have been noticed in § 12.

§ 22. The numerous granitic veins so well known to mineralogists in the mica-schists and gneisses of New Hampshire, Massachusetts and Connecticut, including among other familiar localities, Grafton, Acworth, Royalston, Norwich, Goshen, Ches-

terfield, Middletown and Haddam, seem from descriptions, and from their mineral constituents to be similar to those of Maine, already mentioned. With the exception of Royalston however these localities are as yet only known to me from specimens and descriptions. It is noteworthy that at this last the finely-crystallized beryls are directly imbedded in vitreous quartz, and the same is the case with the blue and green tourmalines of Goshen. A remarkable example of a vein of this character occurs in Buckfield, Maine, described to me by Prof. Brush, where large isolated crystals of white orthoclase, nearly colorless muscovite and brown tourmaline occur in a vein of vitreous quartz. At Paris and at Hebron, Maine, tourmalines are found penetrating crystals of quartz. The flattened tourmalines and garnets found in muscovite at several localities in New England, are well known to collectors, and a curious example of enclosure has been observed by Prof. Brush at Hebron, where crystals of muscovite are encased in lepidolite.

§ 23. The following list includes the principal mineral species found in these granitic veins in New England: apatite, amblygonite, triphylline, autunite, yttrocerite, orthoclase, albite, oligoclase, spodumene, iolite, muscovite, biotite, lepidolite, cookeite, chlorite, chlorophyllite, garnet, epidote, tourmaline, beryl, zircon, quartz, chrysoberyl, automolite, cassiterite, rutile, brookite, uraninite, columbite, pyrochlor, scheelite, and bismutite. As I am not aware that chlorite has hitherto been mentioned as a constituent of these veins, it may be said that it occurs in one at Albany, Maine. To the above should probably be added the rare species nepheline, cauernite and sodalite, which have long been known in boulders of a granite-like rock in Maine. According to information given me by Prof. Brush, green elaeolite with white orthoclase and black biotite occurs in a granitic vein twenty feet in breadth, lately observed in the northwest part of Litchfield, Maine.

§ 24. We have seen that these endogenous veins are found alike in the gneisses, mica-schists, limestones and quartzose strata of this region. They are also met with in the eruptive granites, small fissures in which are sometimes filled with coarsely crystalline orthoclase, smoky quartz, various micas and zircon. Examples of this are seen in the granites of Hampstead, New Brunswick, and Mt. Uniacke, Nova Scotia. The fine green feldspar of Cape Ann, Mass., and the micas, cryophyllite and lepidomelane with
zircon, described by Prof. Cooke, from the same region, occur in veins in the hornblende granites of that locality. Small veins cutting a somewhat similar rock at Marblehead, contain crystallized green epidote with white quartz and red orthoclase.

§ 25. The veins which we have described are frequently of very limited extent, and seem to occupy short and irregular fissures, while in other cases the mineral aggregates which characterize them occur in nests or geodes. This is seen near Fall Brook in the Nerepis valley in New Brunswick, where the red micaeous granite is in one part very friable, and presents irregular geode-like cavities, sometimes several inches in diameter, which are partially filled by radiating prisms of black tourmaline, accompanied with quartz and albite crystals, and more rarely small octahedrons of purple fluorite. The enclosing granite is composed of deep red orthoclase, with small portions of a white triclinic feldspar, smoky quartz and black mica. The conditions seen at this place recall the description of the famous locality of feldspars, etc., at Fariolo near Baveno in Northern Italy. The rock, described as a granite, resembles, in a specimen before me, some of the intrusive granites of New Brunswick, and contains a pink and a white feldspar, with a little black mica. It includes veins of graphic granite, and also spheroidal masses, which differ in texture from the mass of the rock, and present geodes of considerable size, lined with fine large red and white crystals of orthoclase, accompanied by albite, epidote, quartz, fluorite and a greenish mica (or chlorite) all of which, according to Fournet, are so mingled and interlocked as to show that they are of contemporaneous origin. To these are to be added, as occurring in the geodes, prehnite, calcite, hyalite, and specular iron. The orthoclase crystals often have adhering to their opposite faces crystalline plates of albite, which are larger than the planes to which they are attached. The crystals of orthoclase moreover frequently present hollowed-out or hopper-shaped faces, which Fournet happily describes as resulting from the forming of the frame-work or skeleton of the crystals, when the material was not sufficient for their completion. A process analogous to this is often seen in crystallization, whether from fusion, solution or vaporous condensation, giving rise in some cases to external depressions, and in others to internal cavities in the resulting crystals. Fournet ascribes the formation of the geodes in the granite of Fariolo to a process of shrinking, and a subsequent segregation.
filling the resulting cavities, in which he is forced to recognize the intervention of water, though by no means admitting the aqueous origin of veins, since he holds even those of quartz to have been formed by igneous injection. (Geologie Lyonnaise, #278.

§ 26. When we consider the cause which has produced the fissures in the mica-schists and gneisses of New England, which hold the granitic veins already described, it is to be remarked that their comparative abundance, their shortness and their irregularity distinguish them from the fissures which are filled with eruptive rocks. Examples of the latter may be seen near Danville, Maine, where dykes of fine-grained dolerite are posterior to the endogenous granite veins here occurring in the mica-schist. These dykes may be supposed to be dependent upon movements in the earth's crust opening deep fissures which connected with some softened rock far below. Through such openings were extravasated the exotic rocks, whether granites or dolerites,—more or less homogeneous mixtures, often widely different in composition from the encasing rocks. The endogenous veins, on the contrary, are distinguished not only by their more or less heterogeneous and often banded structure, but by the fact that their principal constituents are the mineral species most common in the adjacent strata.

§ 27. Volger has attributed the formation of the openings containing concretionary veins to the force of crystallization, which is shown to be very great in the congelation of water and the crystallizing of salts in cavities and fissures. Such a process once commenced in an opening in a rock would, he conceived, be sufficient to make still wider the fissure, which might be fed by fresh solutions passing by capillarity through the pores of the rock. If this process were to become concentrated around several points, the intermediate space might be so opened that free crystallization could go on, resulting in the production of geodes in veins thus formed.

Fournet, on the other hand, suggests that contraction in the cooling of erupted granites gave origin to the fissures and geodes now filled or partially filled with crystalline minerals at Fariolo, and we may readily suppose that a process of contraction attendant upon the crystalline aggregation of the materials of sedimentary strata, would give rise to rifts or fissures therein. The lesions thus produced in the solid rocks become more or less completely
repaired, if we may so speak, by an effusion of mineral matter from the walls, and thus are generated geodes, irregular masses, and many veins. That the process imagined by Volger may in some cases intervene, and may act subsequently to the one just imagined, is highly probable, though we are disposed to assign it but a secondary place in the production of vein-fissures. It offers however the most plausible explanation of the distortion of the thin-bedded strata already noticed in connection with some of the concretionary granitic veins of Maine, which seem, by a process of growth, to have bent outward the adjacent beds. The vertical transverse veins are, in many cases at least, unsymmetrical, as if they had grown from one side, while the distortion of the beds, sometimes attended by irregular concretions in the banded vein-stone, appears at the opposite wall. The notion that the vein-fissures opened as crystallization advanced, has been defended by Grüner.

§ 28. It is not here the place to discuss how far the greater and deeper fissures of the earth are dependent upon the contraction of sediments, as just explained, or upon the wider spread movements of the earth's crust, though even of these it may be said that they are more or less directly the results of a process of contraction. It should however be noted that while some fissures of this kind are filled with dykes of erupted rocks (§ 26), others hold concretionary veins, which are to be distinguished from the class of veins just described, inasmuch as the openings in which they were deposited evidently communicated with the surface of the earth. Examples of these are seen in the lead and zinc-bearing veins with calcite and barytine, which traverse vertically the carboniferous limestone in England, and enclose in their central portions material of liassic age, abounding in the remains of a marine and a freshwater fauna, which show these veins to have been deposited in fissures communicating with the surface-waters of the liassic period. For a description of these veins by Mr. Charles Moore, see the Report of the British Association, for 1869, and Amer. Jour. of Science, II, 1, 365. Similar evidence is afforded by the existence of rounded pebbles imbedded in veins, as observed in Bohemia, and also in Cornwall, where numerous pebbles both of slate and quartz were found at a depth of six hundred feet in a lode, cemented by tinstone and sulphuret of copper. (Lyell, Student's Elements of Geology, p. 593. Not less instructive in this connection are the observations of Mr. J. A. Phillips, on the silicious veinstones
now in process of formation in open fissures in Nevada (L, E. and D. Phil. Mag. (4), xxxvi, 321, 422, Amer. Jour. of Science, II, xlvi, 138). We cannot doubt that the ancient, like these modern veins, have been channels for the discharge of subterranean mineral waters, and it would seem that while the deposition of the incrusting materials on the walls of the fissure is in part due to cooling, and in part perhaps to the infiltration, in some cases, of precipitants from lateral sources, it is chiefly to be ascribed to the reduction of solvent power consequent upon the diminution of pressure as the waters rise nearer to the surface. This conclusion, deducible from the researches of Sorby on the relation of pressure to solubility, I have pointed out in the Geological Magazine for February, 1868, p. 57. See also Amer. Jour. of Science, II, 1, 27.

§ 29. There is evidently a distinction to be drawn between veins which have been open channels, and the segregated masses and geodes formed in cavities which appear to have been everywhere limited by the enclosing rock. In the former case, a free circulation of the mineral solution would prevail, while in the latter there could be no renewal of it except by percolation or diffusion through the rock. A comparison between the contents of geodes and fissure-veins, whether in granite rocks or in fossiliferous limestones, will however show that these differences do not sensibly affect the mineral constitution of the deposits.

§ 30. The range of conditions under which the same mineral species may be formed is apparently very great. Sorby, from his investigations of the fluid-cavities of crystals, concludes that the quartz which occurs with cassiterite, mica and feldspar in the granitic veins of Cornwall, must have crystallized at temperatures from 200° to 340° Centigrade, and under great pressure, conditions which we can hardly suppose to have presided over the production of the crystallized quartz found in the unaltered tertiaries of the Paris basin, or the auriferous conglomerates of California. In like manner beryl, though a common mineral of the tin-bearing granite veins, like those studied by Sorby, occurs at the famous emerald mine of Muso in New Grenada, in veins in a black bituminous limestone, holding ammonites, and of neocomian age, its accompaniments being calcite, quartz and carbonate of lanthanum (parasite). Small crystals of emerald are disseminated through this argillaceous somewhat magnesian limestone, which contains moreover a small amount of glueina in a condition

§ 31. To these we may add the production of various hydrated crystallized silicates, including apophyllite, harmotome and chabazite, during the historic period in the masonry of the old Roman baths at Plombières and Luxeuil, and by the action of waters at temperatures of from 46° to 70° Centigrade; the presence of apophyllite, natrolite and stilbite in the lacustrine tertiary limestones of Auvergne; apophyllite incrusting fossil wood, and chabazite crystals lining shells in a recent deposit in Iceland. The association of such hydrated silicates with orthoclase, as already noticed (§ 13) and as described by Scheerer, where natrolite and orthoclase envelope each other, showing their contemporaneous formation, with many other facts of a similar kind, lead to the conjecture that orthoclase, like beryl and quartz, and perhaps some other constituents of granitic veins, may have crystallized in many cases at temperatures much lower than those determined by Sorby, and that the conditions of their production include a considerable range of temperature; a conclusion which is however, probably true to some extent, of zeolites also.

It is proposed to continue the subject of granitic veins, and in a third part of this paper to give some facts in the history of the veinstones of Laurentian rocks.