ART. XIII.—*Notes on Granitic Rocks;* by T. STERRY HUNT, LL.D., F.R.S. FIRST PART.‡

(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-porphyries; § 6, Gneisses and granites of New England; § 7, Granitic dykes and granitic veinstones; § 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.

§ 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

* Ann· de Chem. et de Phys., t. xlii, p. 304.

† See Life and Letters of Faraday, vol. ii, pp. 301 *et seq.* and p. 351.

‡ This, with the following part, embraces the matter of the paper read at Troy in August last. It is proposed in the third and fourth parts to describe the Laurentian veins and to consider the subject of eruptive granites.

that in certain of these hornblendic 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 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 feldspar 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 hornblendic and the micaceous 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. Chloritic 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 hornblendic granites, will, in accordance with the views already expressed, be restricted to rocks destitute of quartz. While the disappearance of this mineral from hornblendic granites is held to give rise to a true syenite, the same process with micaceous 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

* This Journal, II, xxxviii, 95. See also Zirkel, *Petrographie*, ii, 179.

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 geognostical 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 micaceous, hornblendic and binary granites to finely granular and even impalpable mixtures of the constituent minerals, constituting the rocks known as felsite, eurite and petrosilex. 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 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 hornblendic 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 hornblendic 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 Rivers in New Brunswick, and in the Cobequid Hills and elsewhere in Nova Scotia. The hornblendic 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 mass 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,

* T. S. Hunt on the Geology of Eastern New England, this Journal for July, 1870, p. 88; also Notes on the Geology of the vicinity of Boston, Proc. Boston Nat. Hist. Soc., Oct. 19, 1870.

nor Virlet d'Aout, who supported his views, however (*ibid.*, iv, p. 493) extended them to feldspathic 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 called 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-Scrope and Scheerer that water had in all cases intervened, and that a few hundredths of water might at 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. Élie 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 characters 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-feldspathic 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, cæsium, 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, (this Journal, 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 this Journal, (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, cæsium, 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 characteristic 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.

[To be continued.]