

9. NOTE on a CONTACT-STRUCTURE in the SYENITE of BRADGATE PARK.

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BUILT into a wall at the ruins, Bradgate, is a block which exhibits a clear junction between the "syenite" and a pale green argillite. Microscopic examination of a fragment which we contrived to detach throws light on an apparent anomaly and offers some suggestions of a wider bearing. The argillite, though in contact with a rock apparently rather coarsely crystalline, is only converted into a natural porcelain; it is "baked" rather than "metamorphosed." Is this due to the refractory nature of the materials or to a comparatively low temperature in the intrusive rock? Microscopic examination shows that within a quarter of an inch of the actual junction the argillite does not materially differ from one of the "flinty slates" common in the Forest. If a slice were cut exclusively from this part it might be passed over without any suspicion of its proximity to a contact-surface. The syenite, macroscopically, is slightly finer in grain, and less definitely mottled with dull green than the normal rock, but on microscopic examination it exhibits some important differences. The line of junction of the two rocks is slightly wavy; for about '02" to '04" the argillite is darkened, and one or two tiny roundish patches occur, occupied by viridite and chalcodony (?), which may possibly be minute cavities subsequently filled. The intrusive rock has at its margin an ill-defined zone, about '06" wide, consisting of a microgranular matrix, in which are many small fragments (apparently of felspar and possibly of quartz), very like one of the more gritty bands which may be seen in the slate on Target Hill. To this succeed crystals of felspar and grains of quartz, say about '04" in diameter, of which the former sometimes exhibit regular crystalline outlines, sometimes seem to be fragmental and scattered in a matrix, described below. These increase so rapidly in number that at least half the slide is occupied by them. The minor interstices are occupied by viridite, but the larger exhibit the "speckled" devitrified structure so common in lava-fragments from the Forest agglomerates and in the Sharpley rock. In one or two, however, somewhat ill-defined, lath-like crystallites of felspar occur, such as may be seen in many trachytic rocks, and these sometimes exhibit an approach to a spherulitic grouping. The figure on the next page (1) is a careful drawing from the most conspicuous instance, and the diagram (fig. 2) gives an idea of the relative proportion of matrix and crystals.

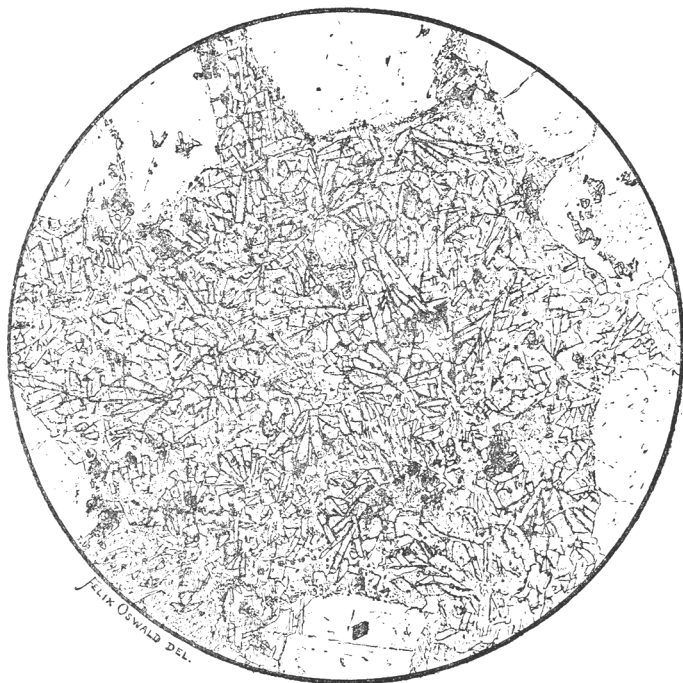
A comparison of the structure described above with that generally presented by the "syenite" in other parts of the Forest* seems to

* See Hill and Bonney, Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 211, and Mr. Teall's fuller and improved description, 'British Petrography,' p. 270, &c.

throw light upon some general questions in the history of igneous rocks belonging to the more acid division.

The consolidation of a rock may be regarded as a function of three variables, more or less independent, these being heat, water, pressure. The usual effect of a falling temperature is probably greatly modified by the second and third; so that, in nature, the order of consolidation of minerals from a magma may vary much

Fig. 1.—Structure of “syenite” close to junction, from Bradgate Park.
The larger grains are quartz and felspar (\times about 30).

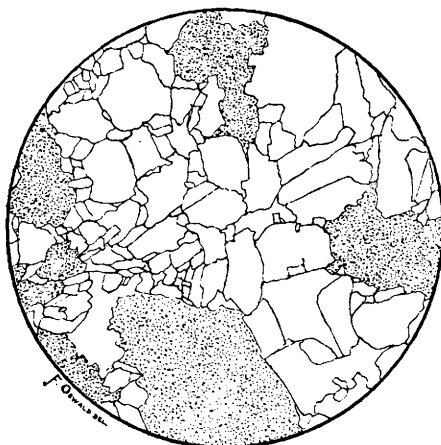


from that of an anhydrous mass, otherwise of like composition, and, in the process of cooling, variation in the amount of pressure or water may produce apparently anomalous or contradictory results*.

* Many of the remarks made in this paper are obviously not new. But, as I have stated nothing which I have not observed for myself, and have had the subject constantly present to my mind since 1877 (see my paper ‘On certain Rock-Structures as illustrated by Pitchstones and Felsites in Arran,’ *Geol. Mag.* dec. ii. vol. iv., and my Presidential Address to the Society in 1885), I have not attempted to stud these pages with references to the works of others, or to devote hours of search through books in endeavouring to ascertain whether a particular idea was published by myself before I could have had it suggested by the writings of another. I have not read any paper which has treated the subject

Thus, for instance, a mineral (*e. g.* a felspar) may be formed in a magma, but afterwards, even though the latter continue to lose heat, may be dissolved by increase either of pressure or of the amount of water present*. At one time, for example, quartz may separate before felspar from a magma, at another, as is more usual, the reverse may occur. Still, as is well known, in most cases a fairly definite order of crystallization exists, and in a holocrystalline mass those which first form are obviously the most idiomorphic.

Fig. 2.—Diagram illustrating relative amounts of quartz and felspar and of matrix in "syenite" from Bradgate Park (\times about 20).



A rock may be either a glass or not a glass. If the latter, it may be (according to the usual division) cryptocrystalline, microcrystalline, or crystalline. The second and third practically pass into one another without any real break, the difference being mainly one of size, but perhaps sometimes of completeness in the segregation of the mineral constituents. Very possibly the first also passes into the second; here, however, differences in completeness of segregation are apparently more significant than those in regard to size. Moreover, a porphyritic structure may or may not exist in every igneous rock. It may be microporphyritic (if a glass) or macroporphyritic. Actual size hardly can be said to matter, so long as one or more minerals are markedly larger than those associated with them. Hence, if, after any one mineral had formed in a magma, the tem-

from quite the same point of view, but I may mention that I am conscious of help, direct or indirect, from papers by, and conversation with, Prof. Judd. Mr. Iddings' most valuable memoir 'On Obsidian Cliff, Yellowstone Park,' and that by Dr. Hatch 'On the Spheroid-bearing Granites of Mullaghderg,' Quart. Journ. Geol. Soc. vol. xlv. (1888) p. 548, contain many useful remarks and references.

* See the suggestive remarks by Prof. Judd in the Krakatoa Report, p. 42, and Geol. Mag. dec. iii. vol. v. p. 1, and the excellent summary of Lagorio's results by Mr. Teall, 'British Petrography,' p. 397.

perature were rapidly lowered and the process of crystal-building stopped, the result would be a porphyritic rock; while if it were slowly cooled this structure might not be developed. It is evident sometimes that the porphyritic structure has been set up during the final consolidation of the rock, as for example in a dyke, where the crystals are wanting near its exterior, set in gradually, and get larger towards the middle; sometimes it is no less evident that these crystals belong to an earlier stage in the history of the rock, and that, whether lava-stream or intrusive mass, it consisted, on assuming its present position, of solids (*i. e.* crystals) embedded in a more or less viscid fluid. The latter may have been in any condition, from a nearly perfect liquidity to one like that of putty or cooling tar. But at this stage the crystals previously formed may be exposed to strains, and so are liable to be fractured. Of course, the temperature of the mass, *ceteris paribus*, will be then comparatively low.

Now it is obvious that the readiness with which a glass is formed depends not only on the circumstances of cooling, but also on the composition of the magma; *e. g.* large masses of glass are very rare among the more basic rocks, and perhaps unknown among peridotites. Moreover, among the acid rocks, we find that in some the glass is comparatively free from microliths, while in others it is crowded with them (felspar usually), sometimes to such an extent that the presence of a vitreous base can only be demonstrated in very thin sections. Suppose, then, a mass be cooling, which is composed of crystals, some of which are felspar, scattered throughout a magma which consists of the constituents required in forming a felspar, together with an excess of silica. This magma in certain cases may solidify as a glass; in others the felspar may be gradually separated, until ultimately the residue is silica, which will then crystallize as quartz*. Now this differentiation of the magma may take place in any of three ways:—(1) The feldspathic constituents may be added to the felspar already existing, and the residue crystallize as interstitial quartz, which may be sometimes of considerable size†. This process supposes considerable freedom of molecular movement: that is, probably, a very slow change. (2) In some cases the magma (probably if it is abundant) may set up an independent holocrystalline structure (as is the case in most porphyritic granites), in which, as a rule, the smaller feldspars are also idiomorphic. (3) In other cases the felspar, though it separate from the quartz and crystallize, may be forced, as it were, to include the quartz; still both the one and the other, though each forms a kind of lattice-work

* Of course I do not forget that water is present, but as this has no direct bearing on my line of thought (though it is a most important factor) I do not mention it.

† In some cases we find little grains or even vein-like masses of a feldspathic mineral which appears to have been occluded from the quartz. In this case probably the feldspathic constituents were not perfectly segregated from the residue when free molecular movement became impossible. But sometimes the felspar forms with the quartz a structure which might be called 'ophitic,' the quartz being analogous in its mode of occurrence to the augite in this variety of dolerite.

crystal, may be for a considerable distance practically a single crystal. This, I take it, is the case where a spherulitic or "graphic" structure is set up. These last structures, then, seem to indicate that the temperature of the mass was comparatively low, but that it fell very slowly. Its constituents, so to say, have ample time to arrange themselves, but the magma is not sufficiently fluid to permit of the molecules travelling for any distance. We may illustrate it by a tightly-packed crowd, where individuals already almost touching one another may contrive to get together into little knots, but when this is done these knots are effectually isolated one from the other. Further, the larger crystals of felspar which already exist form, as it were, rallying-points for the felspathic constituents in the neighbouring glass; or, to speak more exactly, the formation of crystals—as is well known—is promoted by the presence of solids, especially when these are of like composition. So we find that most (perhaps all) rocks which exhibit a micrographic * structure are also porphyritic. In this case we frequently observe that the porphyritic felspars are no longer, strictly speaking, idiomorphic; for their crystals pass abruptly into a "graphic" growth of felspar, separated by quartz. Sometimes, indeed, we observe that the original, commonly idiomorphic, felspar can still be detected by some difference in its optical characters or amount of decomposition. About this has been formed a zone of felspar, apparently not always quite identical in composition, and this zone throws out root-like prolongations, which are sometimes, but by no means always, in optical continuity with it. Probably this diversity of habit is mainly determined by accident, which favours the starting of this growth at particular points. The wedge-like outline frequently assumed by the felspar in rocks with a micrographic structure is probably due to the attempt on the part of the mineral to assume an idiomorphic form. The less regular shapes, such as the branching or root-like varieties, may be due either to the resistance offered by the almost solid (and crystallizing silica), or in certain cases to some slight movements of the mass in the last stages of solidification †. In relation to this question we may notice that at a junction-surface between a holocrystalline rock and a sedimentary one there is not seldom a zone, perhaps about $\frac{1}{50}$ of an inch wide, in which the felspars seem to spring from the junction-surface and grow inwards, like tufts of grass from the ground.

To come, then, to the case of these "syenites" of Charnwood. As already noticed by myself ‡, and as described in more detail by Mr. Teall §, they are characterized, especially in the case of the apparently coarsely-crystalline masses of Groby, Bradgate, Markfield,

* 'Micropegmatitic' of some authors.

† I must not, however, be understood as pledging myself to the assertion that this structure can only be produced in a cooling mass. There are cases where there is much to be said in favour of its secondary origin. But this is no more than may be affirmed (for instance) of spherulitic structure. (See my Presidential Address, Quart. Journ. Geol. Soc. 1885, Proc. pp. 68, 69).

‡ Hill and Bonney, Quart. Journ. Geol. Soc. vol. xxxiv. (1878) p. 215.

§ 'British Petrography,' p. 270.

and Hammercliff, by the prevalence of a micrographic structure; that is, they are not really a uniform holocrystalline rock, but a porphyritic rock, with abundant crystals set in a micrographic matrix *. We can thus assign a reason why this Bradgate syenite has so little affected the neighbouring sedimentary rock, while at Brazil Wood the slaty rock is very highly altered near the junction with the granite, and appreciably so when it is last seen at a distance of thirty yards. But the Mount-Sorrel granite is a holocrystalline rock, and continues to be the same at the junction in Brazil Wood; that is, we may assume that either the temperature of the sedimentaries had been so much raised before the granite was intruded that it cooled very gradually, or (what is perhaps only another way of stating the same thing) that the granite was at a very high temperature. At any rate, the fact that we do not find indications of a selvage to the igneous mass indicates that it did not lose heat rapidly.

But in the Charnwood syenite, mentioned above, we find that a micrographic structure is prevalent throughout the mass, and this, near the junction, is replaced by an ordinary "trachytic" structure or by one which seems to indicate the devitrification of a glass †. Here also we notice that the embedded crystals are often broken, so that the rock almost presents a fragmental aspect. I infer, then, that this mass was, as a whole, at a comparatively low temperature, and consisted, when it reached its present position, of solid bodies (*i. e.* crystals), amounting to at least half the volume of the mass.

But, as has been said, some rocks are almost uniformly holocrystalline. In connection with this it is interesting to notice a structure which might almost be called characteristic of vein-granites, and is not seldom seen to form a kind of selvage, often not more than ·2" thick, to a fairly coarse holocrystalline mass at its junction with a sedimentary rock (which is always much altered). In such cases the crystals are rather small; the felspar often is only partially idiomorphic, and sometimes there seems to have been a "neck-and-neck race" between it and the quartz, and the latter has occasionally contrived to win. This produces a sort of mosaic of quartz and felspar, resembling the microcrystalline structure in many felsites, and even bearing some likeness to certain cases of contact-metamorphism in sedimentaries. The minerals sometimes almost dove-

* Among British rocks which afford excellent examples of this structure may be mentioned parts of the so-called 'Dimetian' of St. David's, and of the granitoid rock of Ercall Hill (Wrekin). Formerly, in consequence of certain anomalies in structure, I regarded these as not of igneous origin, but further study and wider experience have convinced me that I was wrong.

† A specimen collected from the little pit on Holgate Hill several years ago, which was believed to be, if not actually in contact with the sedimentary, all but touching, shows a curious mixture of 'trachytic,' subspherulitic, and imperfect micrographic structure. One lately collected, probably within a yard of the actual junction, shows the micrographic structure, though it is on a very small scale and less regular than in an average specimen of the syenite from Bradgate Park and elsewhere.

tail one into the other, and the felspar occasionally exhibits in the thin sections what are either true inclusions of quartz or sections of lobe-like prominences of that mineral. That is to say, we find in certain vein-granites, though on a smaller scale, the nearest resemblances to a structure which, so far as I know, is characteristic of the granitoid gneisses of the older Archæan. It appears, then, to me that this peculiar structure, which in the case of vein-granites may be traced into the normal structure of granite with fairly idiomorphic feldspars, indicates some mode of what I may call "constrained crystallization;" that is to say, the mass did not possess the complete freedom of molecular movement which has existed in the case of a normal granite. Probably at first it lost heat somewhat rapidly, and so rather quickly assumed a "pasty" condition. The same cause—constraint, due to the mass having previously solidified—may explain the peculiar confused indeterminate structure which is more strictly called cryptocrystalline, for, as I have elsewhere shown, both from my own investigations and those of others, it is evident that considerable separation of constituents may take place without actual melting*. Perhaps cases often have occurred in nature where the mass has not even become plastic, but the action of pressure and water, at a low temperature, has caused the constituents to enter into more stable combinations, though only a small amount of molecular movement has been possible. Thus, in some devitrified rocks it is hardly possible to recognize individual crystals, or say more than that some minute quartz appears to have segregated generally from the originally vitreous mass, the residue of which is a silicate, usually, if not always, crystalline, and in most cases a felspar.

DISCUSSION ON THE ABOVE TWO PAPERS.

Prof. BLAKE was glad to hear that the Peldar-Tor rock was definitely admitted to be igneous. On his last visit to Bardon Hill he had been struck with the evidence of crushing. With regard to what the Authors had inferred to be a pyroclastic rock at Bardon Hill, he believed the same arguments would hold good as those which had been advanced in the case of Peldar Tor.

Dr. CALLAWAY had been puzzled in trying to distinguish pyroclastic rocks from igneous ones in Shropshire. He had not been able to find the slightest evidence of the former presence of an ice-sheet in that county.

Mr. J. W. GREGORY called attention to the limited amount of alteration described by Lacroix in the Trenton Limestone in Canada, when in contact with the pegmatitic as compared with the normal nepheline-syenite.

Gen. McMAHON said he was glad to add his testimony in corroboration of the conclusion arrived at by the Authors regarding the Sharpley and Peldar-Tor rocks. In 1888 he collected good specimens from both localities, those from Sharpley having been selected

* Pres. Address, 1885, Proc. Geol. Soc. p. 65, &c. vol. xli.

under the guidance of Mr. Hill himself; and a careful examination of thin slices under the microscope had satisfied him that the rocks at both places were true lavas and not altered ashes.

The PRESIDENT remarked that the transference of rocks formerly supposed to be clastic into the massive group was a change that would probably require to be rather extensively made on our maps. There was no doubt that once-fused rocks which had undergone deformation tended to simulate pyroclastic rocks.

Prof. BONNEY had formerly been fettered throughout by the wrong identification of the porphyroids of the Ardennes. He felt the difficulty of coming to a decision, but believed that the bulk of the rock at Bardon Hill was pyroclastic, for it did not resemble a flow-breccia, and appeared to have assumed its present condition before being crushed.