

12. *The BUTTERMERE and ENNERDALE GRANOPHYRE.* By ROBERT HERON RASTALL, M.A., F.G.S., Fellow of Christ's College, Cambridge. (Read January 24th, 1906.)

[PLATES XXVII & XXVIII—MICROSCOPE-SECTIONS.]

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I. INTRODUCTION.

IN the western part of the English Lake-District there occurs a large development of igneous rocks, which are conveniently described, collectively, as the Buttermere and Ennerdale Granophyre. This group extends for nearly 10 miles from north to south, and for nearly 5 miles from east to west. In this large area are to be found several different rock-types, which present many features of interest; and, at the suggestion of Dr. J. E. Marr, F.R.S., I have undertaken the investigation of the phenomena shown in this district.

The first and only detailed description of this rock-mass was given by Clifton Ward¹ nearly 30 years ago; and the subject has apparently never been touched as a whole by modern methods, although Mr. Alfred Harker² has published a short description of some specimens from the Wastwater district.

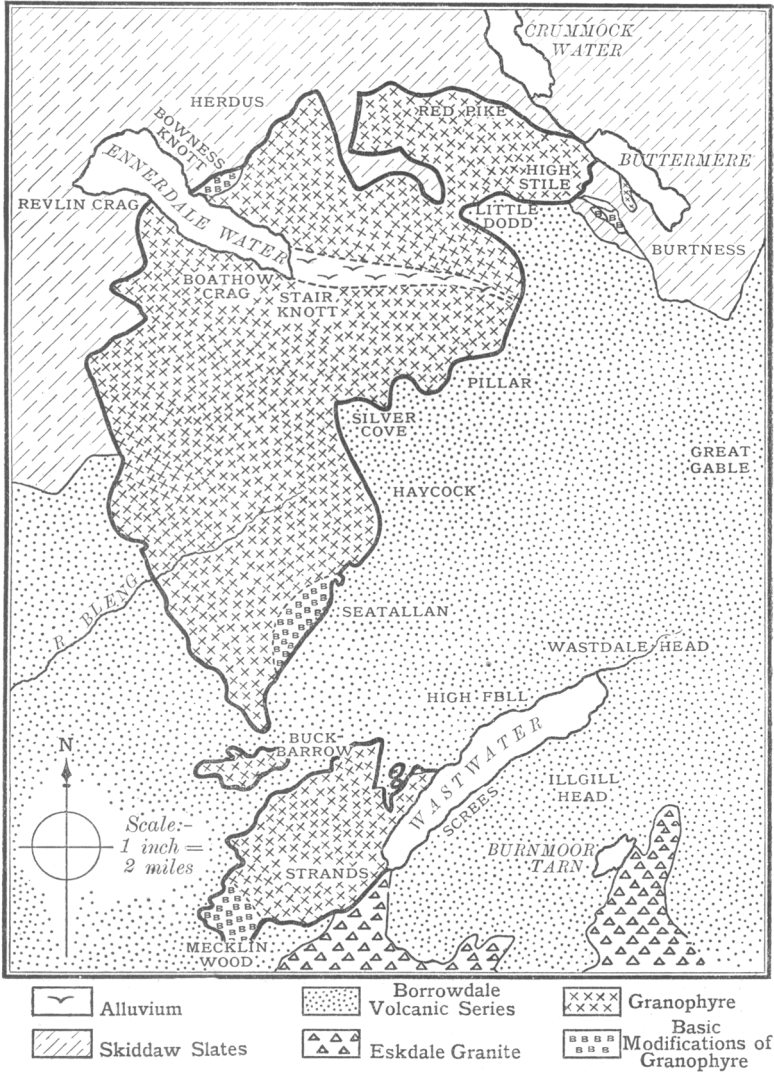
II. FIELD-RELATIONS.

The map (fig. 1, p. 254) shows that the exposure of this group of rocks is very irregular in form: to the west of Buttermere is a somewhat lenticular mass about $2\frac{1}{2}$ miles long by nearly a mile wide, forming the lower part of High Stile, and the main mass of Red Pike and Gale Fell. The southern boundary of this intrusion cuts across the summit of Red Pike; and there is a strong contrast between the rugged crags of High Stile, formed of volcanic rocks of the Borrowdale Series, and the smooth outlines given by the intrusive rocks of Red Pike. This intrusion is connected with a much larger mass to the south by a narrow neck on Little Dodd; and this neck is very conspicuous even from a distance, by reason of the weathering-out of blocks of granophyre, contrasted with the peat-covered Skiddaw Slates and Borrowdale volcanic rocks on the west and east respectively.

¹ Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 14; also 'Geology of the Northern Part of the English Lake-District' Mem. Geol. Surv. 1876, p. 31.

² 'Notes on North of England Rocks' in 'The Naturalist' 1889, p. 209.

Fig. 1.—*Geological map of the district around Ennerdale Water, Buttermere, and Wastwater, on the scale of 2 miles to the inch.*



The larger mass on the south is almost cut in two by the alluvium of the Ennerdale Valley; and it might be supposed that this valley was determined by a strip of softer rock between two intrusions: but I have examined all the lowest accessible points in the floor of the valley, and everywhere found granophyre *in situ*. I have no doubt, therefore, that the intrusion is perfectly continuous; and the detailed mapping at the western extremity certainly suggests that the true form of the intrusion is shown by simply joining up the boundary-lines on each side of the lake. It is probable that Ennerdale is a line of weakness on a large scale, which is due to subsequent earth-movement. There is a great fault running in a north-north-westerly direction, from the head of Smithy Beck towards Floutern Tarn, which shifts the outcrop more than a mile to the north-west, and this helps to make the outline appear more complicated.

The western boundary is fairly simple to the south of Ennerdale Water. It runs in a sinuous manner, with a general southerly direction, for some distance south of the Bleng Valley, and then it suddenly turns to the north-east. Throughout this whole distance of some 6 miles the line is very difficult to follow accurately, although easy enough to map approximately. The outcrop is occasionally shifted for a short distance by small faults, but no important dislocations seem to occur.

Returning again to Ennerdale, a very fine junction-section can be seen in the bed of the River Liza, close to the new bridge below the Pillar mountain. Here the volcanic rocks have been much hardened and injected by veins of granophyre, and this hard band has given rise to a small gorge, which affords a fine exposure. The junction here appears to be very irregular.

From High Beck westwards, the line of junction with the Borrowdale Series presents some interesting features. The faults indicated on the 1-inch map seem to be non-existent; but, from a consideration of the outcrop of the line of junction in relation to the contour-lines, it is evident that the plane of separation between the Volcanic Series and the granophyre is here dipping north-westward, instead of south-eastward as usual. This dip is at a gentle angle, perhaps 5° ; and the upper surface of the granophyre is nearly always brecciated along the plane of junction. Hence, it seems probable that there has been a certain amount of movement along this plane.

On the hillside west of Buckbarrow appears a small lenticular patch of similar rock, and south of this again comes a larger mass, occupying most of the low ground to the west of the foot of Wastwater. This mass is very badly exposed, especially round its margin, and was only mapped with great difficulty.

As will appear from the petrographical descriptions which follow, this great series of intrusions is far from uniform. The great bulk of the rock is highly acid; but in many parts there are more basic modifications, which require separate description. These basic modi-

fifications are always marginal, and numerous traverses have failed to disclose any such in the inner parts of the large masses.

On the whole, dykes are scarce. There are a few interesting examples in Burtness Combe, Buttermere, and a very complex system of dykes on Yewbarrow; but as the latter may, and probably do, belong to the Eskdale Granite, I have not attempted to describe them.

The generalized strike of the Lower Palæozoic rocks of this part of the Lake District is nearly due north-east and south-west, with a south-easterly dip; on the western side the strike swings round more towards north and south, and the outcrop of the granophyre-mass closely follows this somewhat curved line. On the whole, the intrusion seems to be intimately connected with the plane of junction between the Skiddaw Slates and the succeeding Volcanic Series. It may be regarded as consisting of a series of laccolites, which are possibly, in part, of the 'cedar-tree' type. This applies especially to the southern part of the area, where it appears that the intrusion has penetrated into the Volcanic Series. The top of Illgill Head, east of Wastwater, consists of the base of the Scawfell Ashes; hence, the slope covered by the Wastwater Screees must be occupied by the 'streaky'¹ series: therefore, unless there is an enormous fault down Wastwater, the top of the southern granophyre must be well up in the Volcanic Series. The base of the granophyre, near the head of Crummock Water, obviously rests upon the Skiddaw Slates: hence, it appears that the granophyre not only arches up the Volcanic Series, but penetrates into it as well.

The peculiar form of the northern part of the exposure seems most easily explicable on the supposition of two laccolites: a small one on the north, connected with a very large one on the south of it by a narrow neck, which is exposed on Little Dodd. These two laccolites appear to be, on the whole, at the same horizon, namely, the plane of junction of the Skiddaw Slates and the Volcanic Series: this plane seems to have undergone a certain amount of warping, as the result of subsequent movements.

The northern or Buttermere laccolite is of a somewhat lenticular shape: it is certainly truncated at its western end, but it appears to be bounded on this side by a line of disturbance, and it is possibly faulted. Near this north-western corner are a few lenticular patches of Skiddaw Slate resting upon the granophyre, and these suggest that the original outline of this mass was irregular, somewhat of the 'cedar-tree' type. The eastern end of the laccolite is undoubtedly connected with the small igneous complex of Burtness Combe; and there is an isolated mass of granophyre in Burtness Wood, which probably forms an easterly continuation of the same mass.

A series of specimens taken from this laccolite show interesting variations. Those from near the margin [4748-50, 4752]² are

¹ E. E. Walker, *Quart. Journ. Geol. Soc.* vol. lx (1904) p. 89.

² Numbers in square brackets, throughout this paper, refer to slides in the collection of the Sedgwick Museum, Cambridge.

granitic in the usual sense (Pl. XXVII, figs. 1 & 2). A short distance from the margin [4751] granophyric structure begins to appear; specimens taken from the middle of the laccolite, as for example at the head of Near Ruddy Beck, are poorly-developed granophyres [4753].

On the hillside a few hundred yards west of Scale Force, the junction with the Skiddaw Slates is very well seen, and the metamorphism can be well studied here. Close to the intrusion the slate is altered to a very compact greenish hornstone, and the junction is absolutely sharp. The original bedding of the slate is well seen on weathered surfaces, but there is no trace of cleavage; and it is quite clear that the intrusion of the igneous rock was anterior to the movements which produced the cleavage of the Skiddaw rocks.

Along the northern side of this laccolite are a number of lines of disturbance, which have produced small tear-faults crossing the junction at right angles; these are made conspicuous by a great development of hæmatite. The fine waterfall of Scale Force, 156 feet high, is determined by one of these; and the stream has here cut a very deep gorge along the line of weakness.

The second mass is much larger, and the laccolitic form is not here so obvious; it is probably concealed, to a certain extent, by incomplete denudation and faulting. In this case granophyric structure is carried to a very high degree of perfection. The margin of this intrusion is variable in character, sometimes granitic, more often coarsely graphic; and in some localities felsitic, as, for example, in Revlin Crag, on the south side of Ennerdale Water, and at Silver Cove [4754], farther east. The farther we proceed from the margin the finer in texture and more complex is this micrographic or granophyric structure seen to become [4755]; see Pl. XXVIII, fig. 1. The best examples come from near the middle of the exposure, at Mart Knott, Stair Knott, and Sail Hills, south of the head of Ennerdale Water, and in the bed of Woundell Beck, close to its junction with the River Liza [4756-59]; see Pl. XXVIII, fig. 2. Here also the normal rock is traversed by fine-textured veins of an aplitic nature, which show no micrographic intergrowth at all, and are singularly poor in ferromagnesian minerals [4760-61]. They are presumably of later date than the rest.

On the south-east side of this mass, on the flanks of Seatallan, is seen a considerable development of a rather more basic variety, characterized by the occurrence of needle-shaped crystals of ferromagnesian mineral, often an inch long.

In the smaller laccolites, in the Wastwater district, some interesting variations occur; and especially in the neighbourhood of Mecklin Wood, about a mile north-east of Santon Bridge, the whole intrusion becomes very complex, and some peculiar rock-types are found. These are the freshest rocks in the district, and their study has thrown much light on the more weathered examples from the northern part of the area.

III. PETROGRAPHICAL DESCRIPTIONS.

(a) The Normal Rock.

The macroscopic appearance of an average specimen is that of a rather fine-textured granite, usually of a bright pink colour, but sometimes grey with only a slight tinge of red. Near the margin it is often grey or even greenish, owing to the higher proportion of coloured minerals; and in certain localities there are also varieties which are quite dark-grey or blue, but these demand separate description. The rock is very rarely porphyritic to the unaided eye, and dark-coloured 'basic patches' are also scarce. In places the rock is somewhat drusy, and in the neighbourhood of planes of disturbance it is often much stained by hæmatite.

I have examined a large number of slices, which have been selected, as far as possible, so as to illustrate the different types, and the variations that occur in different parts of the mass.

The rock consists essentially of quartz, various felspars, chlorite representing ferromagnesian minerals, and accessories. The coloured minerals generally occur in small proportion only; and, on the whole, the rocks are distinctly leucocratic in character.

Quartz is generally very abundant. It contains the usual fluid-inclusions, which are nearly always very conspicuously arranged in lines; and these lines are often appreciably parallel throughout the slice, as if their position was determined by strains set up during cooling or subsequently. The relations between the quartz and the felspar, with regard to age, are very variable; in the granitic types [4748-50, 4752] the quartz appears to have crystallized partly before the felspar, as in the Shap Granite and parts of the Eskdale Granite. In this case, the quartz occurs in small crystals which sometimes show fairly-good hexagonal outlines, but more often they are more or less rounded in form. In the great mass of the rock, however, the quartz and the felspar have crystallized simultaneously, giving rise to more or less perfect granophyric structure [4755-56, 4758-59].

The felspars are very variable, and include orthoclase, perthite, and plagioclase; in a few specimens a very little microcline appears to be present. The relative proportions of orthoclase and plagioclase vary greatly, but the latter is generally the more abundant; in some slices it appears to be almost the only felspar present. Both kinds of felspar are generally somewhat decomposed, being partly converted into aggregates of small flakes of white mica, and these flakes generally lie parallel to the cleavages of the felspar: wherefore, in most sections, they appear to be arranged in two sets at right-angles. However, the decomposition has rarely gone far enough to mask the twinning, which is generally conspicuous.

In spite of decomposition, it is often obvious that much of the unstriated felspar possesses poorly-developed perthite-structure, and the so-called 'orthoclase' must contain a good deal of the albite-molecule.

In the granitic forms, orthoclase, perthite, and plagioclase all occur as large idiomorphic or hypidiomorphic crystals. The orthoclase and perthite are twinned on the Carlsbad law, and are of quite normal character. In the granophyric forms also, orthoclase occurs in graphic intergrowth with the quartz.

In most examples the dominant felspar is a rather turbid plagioclase, which occurs in fairly well-formed crystals in nearly all varieties. It is commonly twinned on the Carlsbad and albite-laws; the twin-lamellæ are often rather indistinct, owing to decomposition. Occasionally other twins appear, such as the pericline and Baveno varieties. The plagioclase-crystals are sometimes slightly zoned, but the range of composition between the inner and outer zones is not wide. Examination of a very large number of symmetrical sections shows that, in the majority, the extinction is nearly straight. Some examples show extinction-angles up to about 20° ; and in these cases a comparison of the index of refraction with that of quartz proves that andesine and albite are both present.

The analysis tabulated by Clifton Ward¹ is probably not very trustworthy; but, if we assume it to be moderately correct, the percentages of soda and lime which are there stated, supposing all to be combined as felspar, would give an approximate ratio of $\text{Ab} : \text{An} = 6 : 1$. But some of the soda exists as perthite, and the true ratio must be somewhat lower than this.

The determination of the original character of the ferromagnesian mineral of this rock presents a certain amount of difficulty. Clifton Ward regarded it as hornblende, while Dr. Teall, in his 'British Petrography,' merely refers to it as 'green chloritic aggregates.'

In most specimens the coloured mineral is some variety of chlorite, but in a few especially-fresh examples from well-glaciated localities I have found almost unaltered biotite of a yellowish-brown colour, and in the normal rock the chlorite undoubtedly represents this mineral; while, in the more basic modifications from Bowness Knott, Seatallan, and elsewhere, it is equally clear that much of the chlorite is derived from augite.

The chlorite of the normal rock occurs in ragged flakes having the form of biotite; it is of a rather deep-green colour, and strongly pleochroic (a deep green, & pale yellowish-brown). The extinction is straight, parallel to the cleavage of the original biotite. This mineral is only distinguished from green biotite by its extremely-weak double refraction; sections of the ordinary thickness generally give a steel-grey of the first order, while many are completely isotropic. The flakes of chlorite very often enclose rather large crystals of a mineral with high refractive index and strong double refraction: this appears to be epidote. These inclusions are surrounded by a well-marked dark 'pleochroic halo' [4763].

The characters of the green mineral seem to agree best with the variety of chlorite known as pennine, while a few sections

¹ Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 22.

showing rather stronger double refraction may be referred to clinocllore. However, for all practical purposes it is sufficient to regard it as chlorite derived from original biotite. Description of the chlorite derived from augite may be deferred, until the local modifications in which it occurs are dealt with in detail.

Some common accessories are magnetite, apatite, sphene, zircon, epidote, and calcite: they do not call for any special remark. The calcite is always secondary, and so is probably some of the epidote: however, the inclusions of epidote in the chlorite may be original.

A slice [4762], taken from near the margin of the small mass which lies on the hillside west of Buckbarrow, shows a remarkable facies. Instead of being, as we might expect, of very fine texture, it is the coarsest and most granitic type yet obtained. The rock is almost free from coloured minerals, only a very little of the ordinary chlorite being present. It consists of a coarse-grained aggregate of various feldspars and quartz, with typical hypidiomorphic granular structure; in places only is there a very slight tendency to graphic intergrowth of the quartz and feldspar. There is a large amount of feldspar showing albite-twinning, and belonging to oligoclase-albite and albite. The remainder is perthite, in less perfectly-formed crystals, which very frequently have a cross-hatched character, resembling that of microcline in certain sections.

Specimens taken from the southernmost or highest laccolite show the same type of structure as that which is seen in the marginal parts of the larger masses on the north; and they may be described briefly as belonging to the granitic type, with only very slight indications of micrographic intergrowth. Their texture is not conspicuously finer, and felsitic modifications are not found to any extent. The small hill known as Berry How, about half a mile north of Strands, consists of a reddish rock, which in the field appears to resemble strongly the felsitic rock of Revlin Crag and Silver Cove; but, under the microscope, it is seen to be identical with the metamorphosed Borrowdale volcanic rocks of other parts the district.

(b) Felsitic Modifications.

In some localities, as at the head of Silver Cove [4754] and on Revlin Crag, the rock becomes very fine in texture, and in hand-specimens presents a felsitic appearance. In slices it sometimes shows a slight tendency to porphyritic structure. These fine-grained varieties vary considerably in composition. In the specimen from Revlin Crag quartz is practically absent; whereas at Silver Cove it is abundant. The feldspar is generally much decomposed, and coloured minerals are practically absent. These felsitic modifications are all marginal, and may be regarded as chilled edges.

(c) The Greisen.

On the margin of the northern laccolite, a mile west of Scale Force, a curious modification of the granitic rock is to be found [4764-65]. The rock here is of the coarse-textured, non-granophyric type. It consists of quartz and muscovite, without feldspar, but with the usual chlorite in small quantity—part of the quartz is of the normal type, and full of the habitual liquid inclusions; the rest of the rock consists of an aggregate of small flakes of muscovite, embedded in clear quartz. In parts there is a good deal of calcite. This may be described as a greisen.

The structure is here similar to that found elsewhere at the margin, and the ferromagnesian minerals and accessories are quite normal. There can be no doubt that the rock originally contained the usual feldspar, which has decomposed, presumably under the influence of some pneumatolytic agent. The alkali-feldspar molecule has formed quartz and mica, as in the case of the Cornish greisens, while the lime-feldspar molecule has given rise to calcite. In some places the original feldspar is not quite obliterated, and still shows traces of albite-twinning.

(d) Aplitic Veins.

At Stair Knott, on the south side of Ennerdale, the granophyre is traversed by some fine-textured dykes, or veins, of rather peculiar character. The macroscopic appearance of the rock is felsitic, and in slices the structure is seen to be very different from that of the normal granophyre.

The rock [4760-61] consists of quartz, feldspars, chlorite, and various accessories. A few fairly-large porphyritic feldspars are present; they all show albite-twinning and generally pericline-twinning also; the angle of extinction on the albite twin-lamellæ varies from 0° to 20° , and the refractive indices show that the composition ranges from oligoclase to albite.

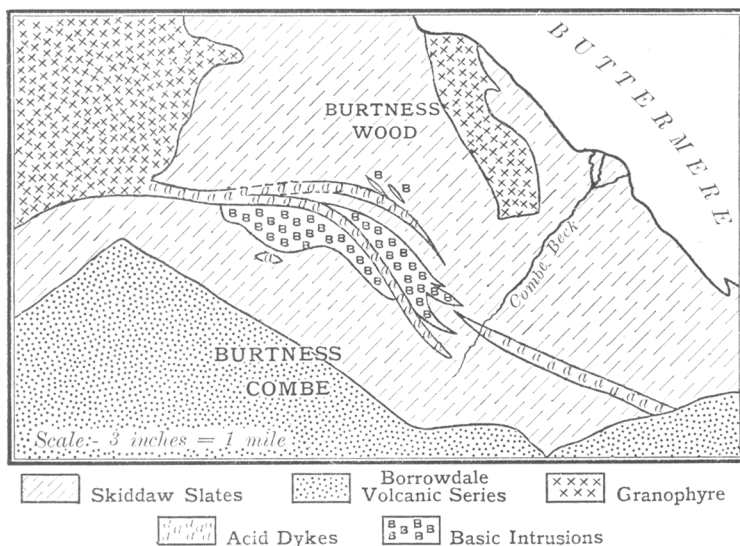
The groundmass consists of a fine-textured aggregate of small grains of quartz, and rather ragged prisms of the same feldspar as in the phenocrysts. The chlorite also is markedly acicular, and consequently the general appearance is somewhat trachytic. Common accessories are small crystals of magnetite and hæmatite, prisms of apatite, and small grains of epidote of various colours, generally green or yellow, but sometimes colourless; this appears to be an original constituent. The amount of coloured mineral is very small, and the bulk of the rock consists of quartz and feldspar in approximately-equal proportions. Hence, it must be of acid composition, and it is most conveniently referred to the aplite-group.

(e) The Igneous Complex of Burtness Combe,
Buttermere.

On the flanks of High Stile, on the west side of Burtness Combe, occurs an interesting igneous complex on a small scale, which has

been briefly described by the late E. E. Walker.¹ This consists of a somewhat lenticular mass of basic rock, about a quarter of a mile long, which at its eastern extremity runs out in a beautiful fringe of dyke-like prolongations, intruded along the bedding-planes of the Skiddaw Slates. Associated with this are some good examples of acid dykes, which are evidently of later age, and show some striking variations. (See sketch-map, fig. 2, below.)

Fig. 2.—*Sketch-map of the igneous complex of Burtness Combe, Buttermere.*



The basic rock may be regarded as a small laccolite, which, owing to the present high south-easterly dip of this part of the district, is exhibited practically in cross-section. The basic intrusion is by no means uniform throughout, but shows some interesting variations. At the margin it is a fine-grained dark-green rock, and the same type is also found in the fringes at the eastern end. Passing towards the centre of the main mass, the rock is seen to become gradually coarser in texture and lighter in colour, until at the centre it is a moderately-coarse rock of doleritic character, with a distinctly pink colour in irregular patches. According to Walker² the silica-percentage of the basic margin is (from two analyses) 50·12 and 49·52. In a specimen of the coarse pink-spotted rock from the centre, I found 56·03, 56·10, and 56·16 per cent. of silica; there is, then, evidently a considerably higher silica-percentage in the middle.

¹ Quart. Journ. Geol. Soc. vol. lx (1904) p. 83.

² *Ibid.* p. 84.

An examination of a series of slices shows that the rock is very far from fresh; but it was, near the margin [4766], an ophitic augite-dolerite of typical structure. The only ferromagnesian mineral present appears to have been augite, which is now represented by actinolitic hornblende; epidote, zoisite, calcite, chlorite, etc., are also abundant, derived from 'saussuritized' feldspar.

Towards the middle of the intrusion [4767] the rock is much fresher, and more acid in character. It contains large idiomorphic crystals of plagioclase, which show extinction-angles corresponding with andesine and oligoclase; there are also some crystals showing twinning on the Carlsbad law only, which must be identified as orthoclase. The chief coloured mineral is ophitic augite, sometimes replaced by actinolitic hornblende and the usual type of chlorite. A fair proportion of quartz is also present; and there is a certain amount of groundmass consisting of a beautiful micropegmatite of quartz and feldspar. All slices of this rock show apatite and ilmenite as abundant accessories; the latter is often converted into leucoxene. Epidote, zoisite, chlorite, and calcite are abundant as decomposition-products.

The outer margin of this rock contains a very high proportion of coloured minerals: in fact, in one slice I estimated them to amount to 75 per cent. of the whole, while at the centre they are much less abundant.

The facts just stated suggest that the magma has undergone a certain amount of differentiation after intrusion, leading to a concentration of basic minerals at the margin; but this explanation seems insufficient to account for all the phenomena, especially the occurrence of orthoclase and quartz in the pink-spotted middle part. This type shows very strong affinities to the neighbouring granophyre, and it seems probable that its peculiar character can best be explained on the supposition that it is a mixture-rock. According to this view, the basic dolerite was first intruded, and while it was still hot and partly liquid in the middle another injection of more acid character took place from the same source, and penetrated into the still unconsolidated centre of the earlier intrusion, producing a hybrid rock, intermediate in character between granophyre and dolerite. Exposures in the field support this view, and it is in accordance with observations made on the Bowness-Knott mass (p. 265).

Associated with this basic intrusion are some beautiful examples of acid dykes. One of these runs parallel to the lower margin of the dolerite for the greater part of the length of the exposure, and some distance below it; perhaps 40 or 50 feet. The other dyke first appears some distance to the east of the eastern extremity of the dolerite, and cuts obliquely across it; on reaching the lower margin of the dolerite it turns parallel to it, and forms the base of the intrusion, until the latter disappears. The acid dyke, however, is continued westward across the flanks of High Stile, and can be traced into the main outcrop of granophyre on the east side of Bleaberry Combe.

This upper dyke is very variable in character. In parts it is a dark greenish-grey, fine-grained rock of somewhat porcelain-like appearance, translucent on thin edges, and with a very splintery fracture. This facies strongly recalls the eurite of Cader Idris, described by Prof. G. A. J. Cole & the late Mr. A. V. Jennings.¹ It passes gradually into a slightly-coarser type, in which banding becomes very conspicuous, in alternate streaks of reddish and blue-grey colours. The darker minerals show a strong tendency to aggregation into rounded patches, and this often passes into very well-marked spherulitic structures. This banding is obviously a flow-structure, and both it and the spherulites are very well brought out by differential weathering. These flow-bands are often very highly contorted, as if the magma had been very viscous during intrusion. This dyke shows a striking resemblance to the rhyolite-dykes of Druim-an-Eidhne in Skye, described and figured by Mr. Harker.² Here also the rhyolitic affinities are very marked, though the dyke is visibly an apophysis of the granophyre. Near the eastern end of the dolerite-mass this dyke is nearly 20 feet thick, and its structure is strikingly columnar; the upper and lower layers are highly contorted, while the middle part is comparatively free from banding: where the dyke is thinner, practically the whole of it shows complex flow-banding.

The microscopic structure of this rock was described by the late E. E. Walker,³ and its silica-percentage was found to be about 72, so that it is a distinctly-acid rock [4768].

I cannot agree with Walker's conclusion that 'the felsite was probably first intruded, and the diabase came up later' (*loc. cit.*). The dolerite-intrusion is most clearly cut by the acid dyke, which must be the later of the two. (See sketch-map, fig. 2, p. 262.)

The lower dyke is very similar in character, but less variable; it is a fine-grained rock of 'felsitic' type, showing no very definite characters except slight banding. It runs parallel to the lower margin of the dolerite, but thins out before reaching the wall on the west of Combe Beck. It can be traced for a long distance westwards across the steep slopes of High Stile, and approaches very near to the upper dyke. Unfortunately the ground is obscured by scree, and very inaccessible, so that its western prolongation is hidden; but I believe that it joins the upper dyke before the latter merges into the granophyre.

The published 6-inch Geological Survey-map shows a long felsite-dyke, running from the south-eastern extremity of the dolerite for a mile or so in a south-easterly direction past Low Wax Knott, with an interruption where it passes beneath the lag-plane. The western end of this is presumably the remarkable mass of spherulitic or

¹ Quart. Journ. Geol. Soc. vol. xlv (1889) p. 433.

² 'The Tertiary Igneous Rocks of Skye' Mem. Geol. Surv. 1904, p. 283 & pls. xi-xii.

³ Quart. Journ. Geol. Soc. vol. lx (1904) p. 84.

orbicular rock described by Walker.¹ However, it is not clear what is the relation of this dyke to those previously described, since there is a great accumulation of fallen blocks at the critical point. They are certainly not directly continuous, but probably they are closely connected.

I have very grave doubts whether the dyke shown in the published map at Wax Knott is really a continuation of the acid dyke of Burtness Combe; my specimen, taken just below the Scarth-Gap path, is a dark-grey rock of basic appearance, and distinctly porphyritic.

(f) Bowness Knott and Herdus.

At Bowness Knott, on the north side of Ennerdale Water, occurs another comparatively-large area of basic rock. This is a mass, roughly oval in shape, and about a quarter of a mile in its longest diameter. On the south-east side, however, it passes into the granophyre in so irregular a manner that its boundary cannot be exactly laid down on the 6-inch map. The basic rock is penetrated by numerous veins of granophyre, which gradually become increasingly abundant, until it shades off insensibly into the main mass.

The greater part of the basic rock [4769-70] is very similar to that of Burtness Combe. It is essentially of doleritic character, but has a few special peculiarities. The felspars are usually idiomorphic, and seem to have a wide range in composition. Zonary banding is common, and the composition ranges from a rather basic labradorite to oligoclase, while a considerable amount of orthoclase appears to be present. Quartz is rare, and there is no sign of micropegmatite. The only ferromagnesian mineral is actinolitic hornblende, representing original augite, and in a few crystals relics of almost unaltered augite can be seen. In places there is a slight tendency to ophitic structure. Ilmenite is abundant, and occurs in rather large crystals.

Near the junction with the granophyre is a basic rock of peculiar character, in which the ferromagnesian mineral shows a very well-marked needle-like habit. It consists of large felspar-crystals, of columnar habit, ranging from labradorite to oligoclase, together with a good deal of orthoclase, long needles of partly-uralitized twinned augite, chlorite, epidote, ilmenite, and apatite. The rock is much weathered, but it is easy to see that the structure is not uniform throughout; in some parts of the slice there is the usual association of chlorite and epidote representing biotite, whereas in other parts the chief coloured mineral is uralitized augite. In places there is a good deal of a microcrystalline groundmass, which appears to contain quartz; but it is not micrographic. Another slice of a similar rock is coarser in texture, and does not show the fine groundmass; apparently quartz is absent from this type.

It is evident that this rock is very variable in character in different

¹ Quart. Journ. Geol. Soc. vol. lx (1904) p. 84.

parts, and the specimen containing a fine-textured groundmass might be described as an augite-porphyrityte. But the evidence shows that these peculiar types are hybrid or mixture-rocks; and in this case the mixture seems to have been very imperfect, thus accounting for the patchy structure. The needle-rock occurs near the very irregular boundary between the basic and acid rocks, and is probably due to the action of a second intrusion of more acid character (namely, the granophyre of the largest laccolite), while the earlier basic intrusion was still hot. It is, therefore, probably due to the remixing of two partial magmas previously separated by deep-magmatic differentiation.

A similar type of 'needle-rock' also covers a large area on the south-eastern margin of the largest laccolite, on the southern flank of Seatallan. In petrographical character it is very similar to the rock described above, and does not require separate treatment.

A similar acicular habit of the augite has been noticed by Mr. Alfred Harker¹ in marginal modifications of the Carrock-Fell Granophyre; and he compares it with the blade-like habit of the biotite on the margins of the Shap Granite and several intrusions of granite-porphyrityte in other parts of the Lake District.

(g) The Wastwater District.

About three-quarters of a mile north-east of Santon Bridge, on the north side of the road to Wastdale Head, are to be seen some exposures of rock of a peculiar character. This marks the south-western limit of the granophyre-intrusion in this district, and is probably another marginal forerunner, like those of Burtness and Bowness.

In hand-specimens this rock much resembles a rather coarse type of the granophyre, except as to its colour, which is more blue or grey, with a few conspicuous red felspar-crystals.

Under the microscope [4771] it is seen to consist of a rather coarse-grained aggregate of idiomorphic prisms of plagioclase-felspar, large irregular plates of orthoclase, and some interstitial quartz, with a considerable amount of ferromagnesian mineral. This includes some chlorite and epidote, but the bulk of it is hornblende, which is pale green or brownish and distinctly pleochroic; much of it shows uraltic character. A few long prismatic crystals now consist of chlorite; and both kinds of ferromagnesian mineral probably represent original augite. Large prisms of apatite and irregular crystals of magnetite are abundant.

The plagioclase-crystals show strong zony banding, and the extinction-angle of the middle part is in some as high as 30°, while in the outer zones it is nearly straight. This shows that the felspar ranges from labradorite to oligoclase.

This rock seems to be another modification of the non-granophyric quartz-plagioclase-augite rock, which is so characteristic of this series; but it differs from the more ordinary examples in the

¹ Quart. Journ. Geol. Soc. vol. li (1895) p. 127.

possession of orthoclase, together with a rather basic plagioclase. This association suggests a comparison with the monzonite-family of Prof. Brögger, and the rock in question shows a distinct resemblance to his quartz-monzonites. Possibly it would be better to regard it as related to the banatites,¹ which are subalkaline rocks of the tonalite-group, containing typically a good deal of augite.

A little farther to the north-east, between Mecklin Wood and the farm known as Burnt House, is an interesting occurrence of a rather fine-textured grey rock, which is much fresher than is usual in this series. It occurs as an irregularly-shaped mass, about a third of a mile long and 100 yards broad at the most. It appears to be entirely surrounded by normal granophyre; but it is very near the margin of the latter, and is no doubt a forerunner like the last-described.

A slice of this rock [4772] is found to consist of plagioclase, biotite, hornblende, augite, and quartz, with accessory magnetite and apatite. The feldspar is in the form of more or less ragged prisms possessing the habit characteristic of the diorites or dolerites; the extinction is nearly straight, showing that it is oligoclase. A little orthoclase is also present. Quartz is abundant, and its occurrence is interstitial, but not granophyric. The biotite is very fresh, deep brown in colour, and strongly pleochroic. Some of the most conspicuous elements in the rock are rather long narrow prisms of a mineral which is usually very pale green or nearly colourless, with a high index of refraction. Some crystals are non-pleochroic and have a wide extinction-angle, up to 45°: others are pleochroic, and have a narrow extinction-angle, usually below 10°, so that both augite and hornblende are present. The hornblende is probably secondary, of uraltic origin. These crystals are, no doubt, essentially the same as the needles of augite which are so characteristic of the margin of the granophyre-mass on the south-west of Seatallan and elsewhere.

The foregoing description shows that the affinities of this rock also are with the tonalites and banatites, rather than with the granites, since orthoclase is quite subordinate. It is essentially an augite-bearing quartz-mica diorite, which is practically the definition of a banatite.

On the south-west side of Mecklin Wood is a rock of a much more basic character. It forms a small mass, which is rather badly exposed just above the stream, and close to the wall bounding the wood. The mass is variable in character, but the bulk of it is a grey rock of moderately-coarse texture, showing well-marked tabular feldspars, much dark mineral, and a little biotite and iron-pyrites.

In slices [4773] it is seen to be doleritic in structure, although many specimens are a good deal decomposed. It consists of zoned columnar feldspars, ranging from labradorite to oligoclase, enclosed in typical ophitic fashion by large plates of a ferromagnesian mineral

¹ W. H. Weed & L. V. Pirsson, 20th Ann. Rep. U. S. Geol. Surv. pt. iii, 1898-99 (1900) p. 471; also Am. Journ. Sci. ser. 3, vol. 1 (1895) p. 467.

which is partly still fresh colourless augite, but for the most part converted into hornblende by uralitization. Some of the hornblende is actinolitic, in aggregates of long slender needles, but much of it is so well crystallized as to resemble an original constituent; it is distinctly pleochroic (bluish-green to pale yellowish-brown), and some patches have a very distinct blue colour. There are also a few flakes of a bright reddish-brown biotite, and abundant patches of ilmenite exhibiting very conspicuous bar-structure.

In the centre of this dolerite-intrusion is a large patch of a very coarse-grained gabbroid modification [4774], which shows crystals of felspar and uralitized augite measuring up to half an inch in length, and plates of ilmenite measuring up to 1 inch in diameter. Scattered through it are abundant flakes of red-brown biotite, measuring up to a quarter of an inch in diameter. Another noteworthy feature of this rock is the occurrence of what, at first sight, look like orbicular patches. A closer examination shows that these are partly-digested xenoliths, since every gradation can be traced—from obvious angular inclusions, up to more or less regular ‘orbicles’ measuring an inch or more in diameter.

No quartz was observed in any part of this dolerite-mass, and it is probably the most basic rock yet examined in this series.

IV. GENERAL CHARACTERS.

It appears from the foregoing descriptions, that this great series of intrusions comprises a large number of rock-types of variable character, but still showing many points of resemblance among themselves. Speaking generally, they may be regarded as products of the differentiation of one original magma; and this differentiation seems to have taken place in two stages, the deep-magmatic and laccolitic phases of Prof. Brögger. There has also occurred, to a certain extent, production of peculiar rock-types, as the result of the subsequent admixture of previously-differentiated partial magmas of the deep-magmatic series.

In both stages, the amount of basic rock produced by differentiation is small, in comparison with the bulk of acid rock; and this suggests that differentiation only continued for a short time, and the variations produced are not extreme.

If we consider the mineralogical composition of the magma as a whole, without regard to small basic modifications, it will be seen to consist of quartz, an intermediate plagioclase near to oligoclase, with subordinate orthoclase and perthite, and a rather small proportion of a ferromagnesian constituent (which crystallized either as biotite or augite, according to circumstances). Such a magma shows more resemblance to the tonalites than to the granites, although it is rather more acid than the typical tonalites, which usually contain about 66 per cent. of silica.¹ According to Clifton Ward² this rock contains about 71·5 per cent.

¹ H. Rosenbusch, ‘Elemente der Gesteinslehre’ 2nd ed. (1901) p. 144.

² Quart. Journ. Geol. Soc. vol. xxxii (1876) p. 22.

The mineralogical composition is singularly uniform, and the more basic modifications consist essentially of the same minerals in different proportions, if we regard the biotite and augite as closely related, an assumption which seems justified by the evidence.

So far as structure is concerned, it is especially characterized by micrographic or micropegmatitic intergrowth, due to simultaneous crystallization of the quartz and felspar.

The earliest phase of intrusion is that of small masses of more basic character, which now occupy a marginal position; these may be described as ranging from dolerites and quartz-dolerites to a type in which the presence of a considerable proportion of orthoclase shows affinities to the quartz-monzonites of Prof. Brögger's classification. This was quickly followed by the intrusion of the main mass, while the earlier injections were in some cases still hot and partly liquid.

A noteworthy feature is the absence of any well-developed series of dykes of the more acid rocks. A few examples of dykes exist in the more northern part of the area, but those in the southern part seem to belong entirely to the Eskdale Granite.

In view of the abundance of garnet-bearing rocks in the central part of Lakeland, it is worthy of notice that I have not observed a single occurrence of garnet in any one of the very numerous specimens examined. The late E. E. Walker noted the occurrence of loose blocks of garnet-bearing rocks in Burtness-Combe Gill, and, chiefly on this evidence, stated his belief that the Buttermere-Ennerdale and Eskdale intrusions were derived from the same magma.¹ He did not see these rocks *in situ*, and I have observed nothing either there or elsewhere to confirm this idea: in fact, what evidence there is points the other way, although it must be admitted that it is chiefly negative evidence.

With regard to the age of the intrusion, I do not feel competent to express an opinion. The only evidence bearing on the point so far obtained, is the absence of cleavage on the north side of the Buttermere laccolite, which seems to show that the Skiddaw Slates on this side were protected from the influence of the great thrusts coming from the south-east, which so strongly cleaved them in other parts of the district. The intrusion was, therefore, previous to the great earth-movements of the later part of the Caledonian series. Whether it accompanied the Ordovician movements of the same series remains to be proved.

On reference to the map (fig. 1, p. 254), it will be seen that the Ennerdale and Eskdale intrusions come together at the foot of Wastwater. It might be expected, therefore, that this locality would possibly throw some light on the question of their relative ages. I have not been able to find any section showing both rocks in contact, since the probable line of junction is much covered by scree-material. Dr. A. R. Derryhouse, F.G.S., kindly informs me that he has been equally unsuccessful; a casual inspection seemed to show

¹ Quart. Journ. Geol. Soc. vol. lx (1904) pp. 84-85.

that the nearest exposures of the Eskdale Granite do not exhibit any marginal characters :—

‘ If, on further study of the neighbourhood of Eastwaite, this proves to be the case, it would point to one of two things : (*a*) Ennerdale rock intrusive in, and therefore later than, the granite; or (*b*) a faulted junction.’

Further work is required before anything definite can be said on the subject. I have much pleasure in expressing my thanks to Dr. Dwerthyhouse for this interesting note.

V. GRANOPHYRIC STRUCTURE.

As before stated, a detailed study of a large number of slices from different parts of these intrusions has shown that there exists a good deal of variation in different parts of the mass, and these variations seem to be arranged according to certain definite laws. From the field-evidence, it is clear that the intrusion, as a whole, forms a series of laccolites of varying size, which are sharply marked off one from the other. If we examine the distribution of the different rock-types in any one laccolite, we find a certain regularity of distribution, as follows :—Near the margin of the laccolite the rock shows a structure nearly approaching that of the normal acid plutonic rocks, with scarcely a trace of graphic intergrowth; a short distance from the margin, graphic structure begins to make itself manifest, at first of a very imperfect and irregular type; and, as we approach the centre of the visible mass, this intergrowth becomes continuously finer in texture, and of an increasingly-perfect micropegmatitic structure. In some specimens from near the head of Ennerdale Water in particular, this intergrowth becomes so intimate in character as to be scarcely capable of resolution by the ordinary powers of the microscope, and no doubt it also exists in a degree of fineness beyond the limits of visibility. Some of these finer types resemble certain forms of perthite, while others show a very strong likeness to photomicrographs of alloys of metals. This may also be expressed by saying that the structure in the inner parts of the laccolites approaches more and more closely to a molecular mixture of quartz and felspar, which may also be regarded as a solid solution.

The micropegmatite is of several different types. In one very common structure, large and more or less porphyritic crystals of felspar are surrounded by a sort of ring or fringe of micropegmatite, and the felspar of this fringe is in optical continuity with the large crystal. Structures of this sort seem to occur in connection with both orthoclase and plagioclase. Mr. Harker¹ has noted that, in some cases, crystals of plagioclase are surrounded by a narrow zone of orthoclase, and that by micropegmatite, and the felspar of the micropegmatite has the same orientation as this zone of orthoclase. However, this is not always the case, and many crystals of plagioclase are surrounded by a fringe of this nature without any intervening orthoclase. If the central crystal is small, the structure becomes somewhat spherulitic; but, unless a nucleus of this

¹ Quart. Journ. Geol. Soc. vol. li (1895) p. 128.

kind is present, the tendency to a centric arrangement of the quartz and felspar is not so marked as in many granophyres.

Micropegmatite also occurs very commonly in an interstitial manner, between more or less idiomorphic crystals of felspar or ferromagnesian minerals. Several different kinds of micropegmatitic structure may be distinguished, besides the fringing variety above mentioned: for instance the platy, the triangular, and the feathery types. Some of these apparent differences are doubtless due to the varying directions in which the sections are cut, and this almost certainly applies to the triangular and platy types. Some examples have a very strong resemblance to certain forms of perthitic structure; and, in some specimens, examination with a higher power shows that, what appear to be homogeneous and idiomorphic felspar-crystals under a low power, are in reality extremely fine-textured intergrowths of quartz and felspar.

It has been pointed out by many writers that mixtures of two substances, in a proportion approximating to the eutectic ratio, frequently show structures resembling micropegmatite; and it is now believed that ordinary micropegmatite is a eutectic of quartz and felspar. According to Prof. Vogt,¹ the eutectic ratio for quartz and felspar is 26:74; his figures apparently apply to orthoclase, and it is possible that the ratios may be slightly different for plagioclase.

The eutectic mixture would be the last to crystallize; and so we should naturally expect to find micropegmatite in the inner parts of the mass, which remain longest in the liquid state.

It appears, therefore, that in the case of the Ennerdale Granophyre the conditions of cooling were such that crystallization went on from without inwards, leading to the successive supersaturation of the magma for the different constituents, according to the principles laid down by Prof. Morosewicz and others. The course of crystallization was such that the still molten residue approximated more and more closely to the composition of the eutectic, and therefore finally solidified as micropegmatite.

This is in accordance with the idea put forward by Prof. Morosewicz² and Dr. Teall.³ These processes, however, seem to be controlled by other factors, such as rate of cooling and pressure. The true deep-seated plutonic rocks, which have consolidated under a great thickness of rock-cover, do not show much graphic structure. On the other hand, this structure is very well-marked in many rocks which appear, from independent evidence, to have consolidated under a comparatively-thin covering, although occurring in large masses: as, for example, many of the Tertiary intrusions of North-Western Europe. This suggests that pressure is probably an important factor in the case, and that pressure alone, or pressure and rate of cooling conjointly, determine in any particular instance whether an acid magma shall crystallize as a granite or a granophyre.

¹ 'Die Silikatschmelzlösungen' pts. i & ii, Vidensk. Selsk. Skrifter, 1903, no. 8 & *ibid.* 1904, no. 1; see also review by A. H. in Geol. Mag. 1905, p. 132.

² Tscherninak's Min. Petr. Mitth. n. s. vol. xviii (1899) p. 1.

³ Presidential Address, Quart. Journ. Geol. Soc. vol. lvii (1901) p. lxxv.

VI. SUMMARY AND CONCLUSION.

From the facts put forward in this paper, it may be concluded that the Buttermere-Ennerdale intrusion is an excellent example of an acid magma which has crystallized under the peculiar set of conditions that give rise to a very perfect development of granophyric structure. These conditions are probably, to a certain extent, intermediate between those of the plutonic and the true hypabyssal rocks.

Besides the normal acid rock which composes the bulk of the intrusions, there are some marginal patches of a more basic character, showing obvious genetic relationship, and slightly earlier in point of time than the intrusion of the acid rock. These basic forerunners afford evidence of partial differentiation of the magma before intrusion, an example of Prof. Brögger's deep-magmatic differentiation. There is also some slight indication of laccolitic differentiation.

Considered as a whole, the petrographical character of the magma shows closer affinity to the tonalite-group than to the true granites, although it is somewhat more acid than the majority of the tonalites. The more basic types include dolerites, quartz-dolerites, and a rock-type intermediate between quartz-dolerites and granophyres, for which no satisfactory name seems to exist. There is also a development of peculiar rock-types, as the result of the re-mixing of previously-differentiated partial magmas of an acid and a basic character respectively.

A study of the distribution of different types of granophyric structure shows a certain regularity of arrangement, and an attempt is made to reconcile these with known physical laws, especially with reference to eutectics; and it is concluded that the structure is the result of crystallization under conditions intermediate between those which produce typical plutonic and hypabyssal rocks.

It was originally my intention to deal also with the study of the very interesting metamorphism brought about in the Skiddaw Slates by these intrusions, but pressure of teaching work during the last two years has prevented me from carrying out this intention. I have collected a large amount of material, and hope soon to be able to continue the investigation.

In conclusion, I have much pleasure in expressing my hearty thanks to Dr. Marr for much kind help and encouragement, without which the work would have been impossible, and also to Mr. Alfred Harker for much help in the petrological part of the work. My best thanks are due to Mr. W. G. Fearnside, M.A., F.G.S., for his kindness in taking the photographs for illustrations. I am also greatly indebted to Mr. J. P. Millington, Mr. Bernard Smith, and Mr. B. Schön for much pleasant companionship and help in the field.

EXPLANATION OF PLATES XXVII & XXVIII.

[All the figures are magnified 21·5 diameters.]

PLATE XXVII.

Fig. 1. [4750] Granitic margin of the Buttermere laccolite, near Scale Force, showing interstitial quartz.

2. [4748] The same, showing idiomorphic plagioclase.

PLATE XXVIII.

Fig. 1. [4755] Granophyre, Boathow Crag, Ennerdale, half a mile from the margin, showing micropegmatite of a medium degree of fineness.

2. [4759] Granophyre, Sail Hills, Ennerdale, 1½ miles from the margin, showing micropegmatite of very fine texture.

DISCUSSION.

The PRESIDENT regretted the absence of the Author, owing to illness. He welcomed the very interesting paper, and congratulated himself that he had suggested that the Author should undertake the study of these rocks. The Author had referred to Clifton Ward's work—work which was naturally acknowledged by all who had subsequently worked in the district. In Ward's time the study of differentiation of magmas had not been extensively followed, and the Author had taken advantage of work which had been done in this direction, with very good results. He had been well advised in alluding but briefly to the relationship between the granophyre and the 'tectonics' of the district. The paper was really the first part of a study of the area, the second part of which would deal with the metamorphism.

Dr. C. G. CULLIS said that he had been interested to hear that, from a consideration of the granophyric structures of the mass, the Author had arrived at the conclusion that it must have been formed under conditions intermediate between the plutonic and the hypabyssal; and it had occurred to him that the accuracy of that conclusion might, to some extent, be tested in an interesting manner. The Buttermere and Ennerdale Granophyre was one of at least three masses of acid igneous rocks which, in that region of the Lake District, had been intruded into or against the Skiddaw Slate. The other two he had in mind were the Threlkeld (St. John's) Microgranite and the Skiddaw Granite. Of these the latter had consolidated under typical plutonic conditions, the former under hypabyssal. In the case of the plutonic rock, the contact-metamorphic effects produced in the Skiddaw Slate were of the most striking character, the sediments having completely recrystallized for some hundreds of feet, at least, from the junction; but in that of the hypabyssal rock the effects had been very slight, being limited to the hardening of the slate at the junction, so as to form a selvage not more than a few inches thick. If the Buttermere and Ennerdale Granophyre had indeed been formed under conditions intermediate between the plutonic and the hypabyssal, it might

FIG. 1. $\times 21.5$

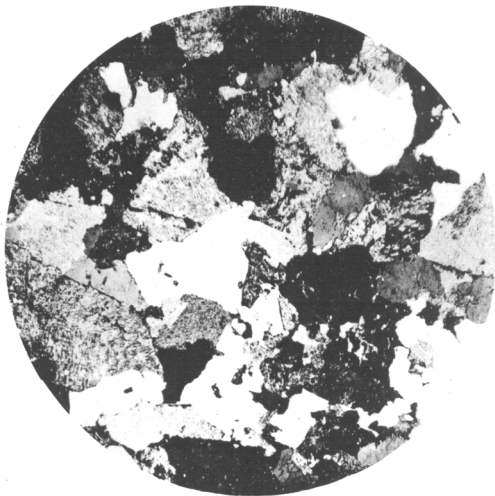


FIG. 2. $\times 21.5$



GRANITIC MARGIN OF THE BUTTERMERE LACCOLITE.

FIG. 1. $\times 21.5$

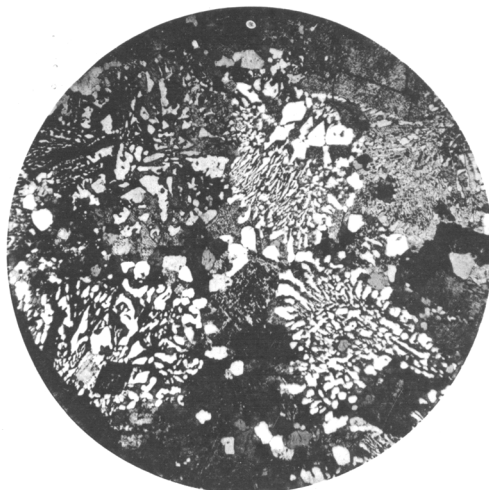


FIG. 2. $\times 21.5$



ENNERDALE GRANOPHYRE.

reasonably be expected that the contact-metamorphic effects produced by it would also be of an intermediate character, and he suggested that a comparison of the three cases might perhaps afford evidence confirming the Author's views.

Mr. J. V. ELSDEN drew attention to the fact that the Author's interesting conclusions with regard to the influence of pressure upon the formation of a granophyric structure seemed to be opposed to those of Prof. Vogt, who, after an exhaustive study of analyses by Lagorio and others, had strongly expressed the opinion that even considerable differences in the depth at which consolidation takes place can have very little effect upon the eutectic composition. With regard to the occurrence of micropegmatite in the interior portion of the mass, this was what would be expected of the product of the final consolidation of the mother-liquor. The rule, however, did not appear to be universal, for an instance had come before the speaker's notice, in the enstatite-diorite of Carnedd Lleithr, near St. David's, in which the only pronounced micropegmatite seemed to occur quite on the extreme margin of the intrusion.

Prof. WATTS expressed his regret at the Author's absence and the cause of it. He remarked that Mr. Fearnside was more or less responsible for the singularly-perfect photographs shown on the screen, which enabled hearers to follow with ease the necessarily somewhat technical descriptions embodied in the paper. Dr. Teall had been the first in Britain to direct attention to the part played by eutectics in rock-magmas, and had tabulated analyses of numerous micropegmatites showing that they had a practically-uniform composition. His conclusions had been driven home by all the most recent work on the crystallization of alloys.

Mr. W. G. FEARNSIDES, in the absence of the Author and in reply to Dr. Cullis, explained that the question of the metamorphism produced by the granophyre was still *sub judice* and was being worked at by the Author. He commented upon the enormous extent of country which must be covered in the course of such an investigation; but thought that, so far as the Author had gone, the metamorphism was certainly found to be of a type intermediate between that around the Threlkeld Microgranite and that of the Skiddaw-Granite aureole. As a further example of a tonalitic granophyre, in which the centre of the mass was finer-grained and more definitely and more minutely micropegmatitic than the margin, he would mention the rock-mass which was variously known as the Tan-y-grisiau Syenite and the Ffestiniog Granite: this is intrusive into the slates and flags which immediately underlie the Ordovician Volcanic Series of North Wales. In this mass also there is a tendency, for certain parts of the marginal granitic or granulitic portion, to lose its felspar and pass into a sort of secondary greisen.