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As rapidity of cooling appears to be essential to their production, it may perhaps be inferred that a similar condition has limited the natural perlitcs. In that case, it is suggested that a gradual passage from the complete structure on the surface to the existence of the rectilinear cracks only, and finally to the unbroken glassy magma at the centre, might be traceable in the perlitic masses of the field; and it would be of interest to learn from geologists who have opportunities for such study whether a gradation of this kind actually occurs.

## VI. — SOME NEW POINTS IN THE PRE-CAMBRIAN GEOLOGY OF ANGLESEY.

By C. CALLAWAY, M.A., D.Sc. London, F.G.S.

WITH NOTES ON SOME OF THE ROCKS.

By Prof. T. G. BONNEY, M.A., etc.

RECENT researches in Anglesey, made with a view to assist my investigations into the Pre-Cambrian rocks of Shropshire, have led me to certain results, some of which I now submit to the geological public. In venturing to differ, in some respects, from so high an authority as Prof. Ramsay, I wish to bear testimony to the great value of his descriptions of the Anglesey rocks in his magnificent work on the Geology of North Wales. I have had the satisfaction of finding that Prof. Bonney's determination by the microscope of some of the more difficult rocks substantially agrees with my own opinion formed on hand specimens, and am under great obligations to him for permitting me to append his notes to this paper.

The term "gneiss" is restricted in this article to a schistose compound of quartz, felspar, and mica or hornblende, and is not applied to a rock in which foliation is not quite distinct; the term "granitoidite" being employed for certain granitoid rocks for which the word "gneiss" has sometimes been used. Chlorite is common in the Anglesey gneiss, but it is hardly rash to infer that it is a decomposition product of hornblende or a magnesian mica.

## A.—EVIDENCE OF PRE-CAMBRIAN AGE.

It is well known that the Survey has mapped the schistose rocks of Anglesey as metamorphic Cambrian and Silurian, with a great granite band of intrusive origin; but recently the clastic origin of this "granite" has been maintained by Prof. Bonney after microscopic examination, and that author and Dr. Hicks are of opinion<sup>1</sup> that the rock is contemporaneous with the Dimetian of Twt Hill and St. Davids.

Of the accuracy of these views I have no doubt, and I am able to furnish confirmatory evidence on both points. First, as to the clastic origin. North of the Holyhead Road, north-west of Gwalchmai, is a faulted mass of the granitoidite with a steep escarpment to the south-east (Fig. 4). The lower part of the scarp is a bedded breccia, containing fragments of a sort of hornstone. It dips at a high angle to the north-west, and passes up into granitoidite with distinct bedding, which, in its turn, passes up into the ordinary

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxv. pp. 302 and 307.

amorphous type. At many points round Llechyn farwy and Llandrygarn, as will be shown in detail, the granitoidite is clearly interstratified with schist, and passes into it both horizontally and vertically. As confirming the identity of the Anglesey and Twt Hill granitoidite, the following fact is of importance. Messrs. Bonney and Houghton<sup>1</sup> have detected at Twt Hill a passage between the granitoidite and a quartzose conglomerate with a south-east dip. I have visited this section, and, having examined the rock inch by inch, I can entirely confirm their identification. There are no signs of a fault between the granitoidite and the conglomerate, and the transition between the two is gradual and unbroken. I have had the good fortune to discover this identical conglomerate in Anglesey. It is exposed in two quarries near Nebo, two miles south-east of AmIwch, dipping to the north-west at a high angle. Lithologically it is perfectly indistinguishable from the Twt Hill rock; the quartz has the same glazed surface, both conglomerates contain disseminated crystals of cubic pyrites, and are tinged with the same dingy purple colour. I could find no granitoid rock in these quarries, but the ordinary granitoidite occurs on about the same strike, one-third of a mile to the north-east. That this conglomerate is not Cambrian or Ordovician<sup>2</sup> is proved by the fact that in these quarries black Ordovician (Carodoc or older) shales rest upon its upturned edges. It is also associated with bands of quartzose grit as in the Twt Hill locality.

The sedimentary origin of the granitoidite being proved, it remains to demonstrate that it is of Pre-Cambrian age. The unconformity between the Ordovician group and the conglomerate of Nebo, just noticed, might perhaps be considered decisive of the question. If this be denied, we are thrown back upon the hypothesis that, between the Cambrian and the Caradoc periods, the older series was metamorphosed into granitoidite and schist, tilted up at a high angle, and largely denuded. This, I presume, no geologist will maintain. The evidence from included fragments also tends in the same direction. Prof. Bonney<sup>3</sup> noticed a pebble of the granitoidite in the Cambrian conglomerate of Llyn Padarn, and I have since observed that such inclosures are not uncommon. Prof. Ramsay furnishes similar testimony.<sup>4</sup> He describes the "Silurian" conglomerate of Anglesey in the following terms:—"The pebbles of the conglomerate are sometimes six or eight inches in diameter, and, taken from different places at random, they consist of white quartz, grey quartz-rock, mica-slate, green schist, jasper, purple slate, a granitic rock of quartz and felspar with sometimes a little mica, blue felspathic trap, dark green hornblende rock, and chlorite." I have seen this conglomerate in several localities, and could in all material points confirm, were it necessary, the above description. All of the varieties named occur in the metamorphic groups of Anglesey.

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxv. p. 322.

<sup>2</sup> I have adopted Mr. Lapworth's name (Geol. Mag. Jan. 1879) for the rocks called "Lower Silurian," that is, the groups from the Arenig to the Caradoc inclusive.

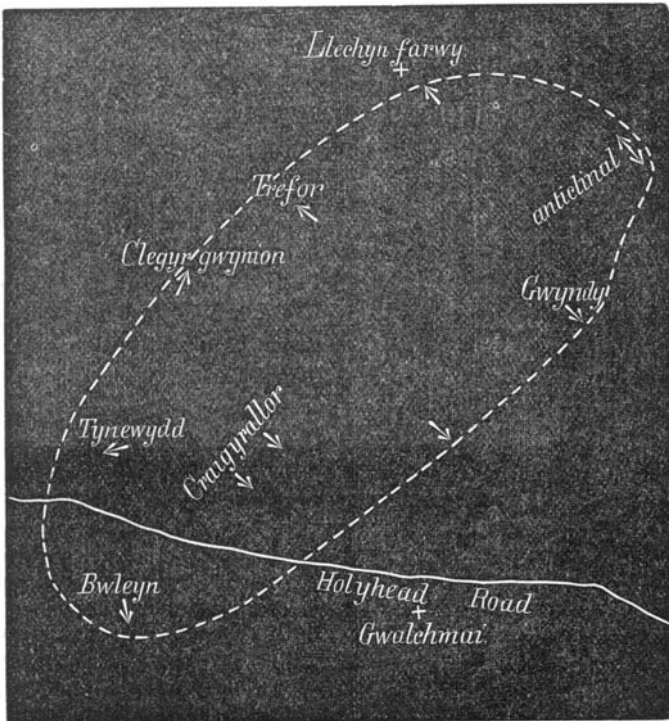
<sup>3</sup> Quart. Journ. Geol. Soc. vol. xxxv. p. 316.

<sup>4</sup> Geology of North Wales, p. 195.

B.—CONTINUITY OF THE GRANITOID SERIES WITH AN UNDERLYING GNEISS.

(a). *The Craig yr Allor anticlinal.*—Dr. Hicks<sup>1</sup> states that the Dimetian granitoidite is the “base-line or axis” of the Pre-Cambrian rocks of Anglesey. From this conclusion I am compelled to differ. I do not here discuss the details of the group or groups which underlie the Dimetian: I am only concerned to prove that it passes down without a break into a great schistose series. The

FIG. 1.—Plan of the Craig yr Allor anticlinal.  
Scale: One inch to the mile.



The arrow-marks indicate dips of dark gneiss. The dotted line is the boundary between the gneiss and the granitoidite.

evidence of this statement is absolutely complete. In the very centre of the granitoid “axis,” rises a dome of dark gneiss, throwing off the granitoidite in all directions, and passing up into it through beds of an intermediate lithological character. This dome is elliptical, and is three and a half miles long by about one mile and a half broad, its larger diameter striking north-east in agreement with the general strike of the district. It lies mainly north of the Holyhead Road, and is represented, in part, by the patch coloured as

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxv. p. 302.

“Altered Cambrian,” surrounded by “granite,” on the Survey Map. The most southerly point in this area at which I have observed the schist is at Ty newydd, half a mile south of the Holyhead Road, and it disappears under the granitoidite at the north-east extremity of the ellipse near Seri fach, one mile and a half east of Llechyn farwy, in the very centre of the granitoid band. Its axis lies a little west of the craggy ridge of Craig yr Allor.

*Proof of the Anticlinal (Fig. 1).*

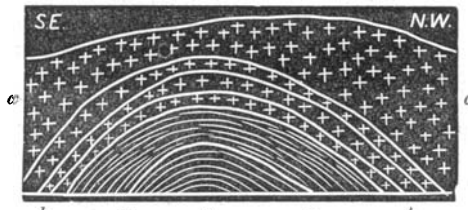
Commencing at the south end, we find at Bwleyn, north-west of Llanbeulan, quartzose chloritic schist with a high S.S.E. dip. At Ty newydd, one-third of a mile to the west, the rock is similar. Coming round to the north-west to the north of the Holyhead Road, we find, at another Ty newydd (Note 1, p. 126),<sup>1</sup> an exposure of dark gneiss with folia planes dipping at a low angle to the W.S.W. A mile to the N., at Clegyr gwynion, I obtained the first clear proof of the infraction of the schist. Approaching the farm, the foliation lines are seen striking to the S.E. across the road. Climbing the wall to the right, I came upon a projecting crag composed of dark gneiss, very micaceous, interstratified with thin bands of nodular granitoid (Note 2, p. 126) rock. About three yards to the N.E. is another boss composed of similar material; but in this case the thin bands are of schist, the rock being mainly granitoid. The dip in these passage beds is at a moderate angle to the N.E. A few yards further on is a large craggy mass of granitoidite, in which I could detect no schistose intercalations. These rocks, it will be seen, show a deviation from the normal N.W. dip, and this is not the only locality in which I have noticed that the dome is disturbed or fractured. This is, of course, precisely what was to be expected in such a shattered district as Anglesey. Four hundred yards to the E., the gneiss dips to the N.W. A little further to the N.E. is contorted dark gneiss, with broad quartzo-felspathic folia dipping at a low angle to the N.W. and N.N.W. Higher beds, the strikes of which are seen at the junction of the two roads S. of Trefor, display the normal N.W. dip. Here also are seen nodular bands of granitoid rock. A mile N.E. of Trefor, E. of Llechyn farwy, hornblende and micaceous schists are well exposed, dipping at a high angle to the N.W., and passing up through nodular passage beds into the granitoid rocks seen N. of the church.

Coming round to the N.E. end of the dome, we find the very apex of the anticlinal. This is seen about a mile S.E. of Llechyn farwy, at the second “e” of Pentre'r felin in the Ordnance Map, in a field E. of the road. The beds are bent into a perfect arch, and are composed of alternations of coarse and fine-grained dark-green gneiss, with a granitoid band in the middle. The axis of the anticlinal is seen to trend to the N.E. Granitoidite lies a few yards to the E. Following the axis to the N.E., we find in a quarry by a farm the

<sup>1</sup> The numbers within brackets refer to Prof. Bonney's appendix (pp. 125-126). This rock looks like a hornblende-gneiss, but Prof. Bonney considers the dark mineral a mica. A great part of the upper gneiss seems hornblende, but I have generally used the term “dark” throughout this paper, in deference to his opinion.

highest beds of the schistose arch. The ordinary dark gneiss is overlain by a band of granitoid gneiss, a rock like granitoidite, but with hornblende or micaceous folia developed in sufficient abundance to convert it into a true schist. This passage bed is overlain by ordinary granitoidite, which also lies in mass to the N.E.

FIG. 2.—Anticlinal N.E. of Pentre'r felin.



*a* = Dark gneiss.                      *b* = Granitoid gneiss.                      *c* = Granitoidite.

East of the anticlinal, the dip, exclusive of minor undulations, is regular to the S.E. The best section is seen to the S.E. of Gwyndy, which occupies a position corresponding to Llechyn farwy on the opposite side of the axis. Just opposite the junction of the two roads, green schist dips at a low angle to the S.E. This is overlain by passage beds (granitoid gneiss), which undulate for about 200 yards, and then plunge to the S.E. under massive granitoidite. Green schist appears at intervals to the S.E., but the band between Gwyndy and Bodwrog is mainly granitoid. Skirting the S.E. margin of the schist anticlinal, we find, about a mile S. of Gwyndy, the granitoidite resting on mica-gneiss; the latter dipping to the S.E. The junction is evidently a fault, for (1) there are no passage beds, (2) the mica-gneiss is not the summit of the schistose series, and (3) greenstone breaks up through the Dimetian a few yards to the E. of the junction.

Between the last spot and Bwleyn, the point from which we started, the ground is occupied by the broken ridge of Craig yr Allor. These rocks consist of black and dark-green gneiss, sometimes chloritic, dipping S.E. To the W. of the ridge, the gneiss is massive, and contains epidote. At one spot, unrounded fragments of quartzite are included, and weather out sharply on the surface. Granitoid concretions are not uncommon, composed mainly of felspar, with a little quartz and some chlorite. The Holyhead Road passes across the anticlinal, about half a mile S. of Craig yr Allor, and rocks of the ordinary types are exposed at intervals on both sides.

These details clearly show that the gneiss passes under the Dimetian to all points of the compass, and that it forms an elliptical quaquaversal anticlinal of Pre-Dimetian age. The presence of beds of passage wherever the section is unbroken is of great interest, proving that the Dimetian granitoid group is simply the continuation of an older series.

(*b*). Section at Gaerwen in the Menai anticlinal.—On the Survey Map, two bands of "gneiss" are indicated, the more easterly passing

through the word "Caerwen," the other about half a mile west, at the great fault which brings down Permian rocks against the schist. I have run a section across this area from S.E. to N.W., with the following result:—

(1). At the windmill at "Caerwen." Chloritic mica-schist or gneiss with thick quartz folia. Strike N. and S. Dip vertical, or a little to the W. Small quarry a few yards N. of windmill. Hornblende-gneiss<sup>1</sup> (Note 3, p. 126), indistinguishable from a variety at Craig yr Allor, foliation planes N. and S., passing into a rock in which foliation is obliterated, and which therefore might easily be taken for diorite. The same passage is also seen in the Craig yr Allor area.

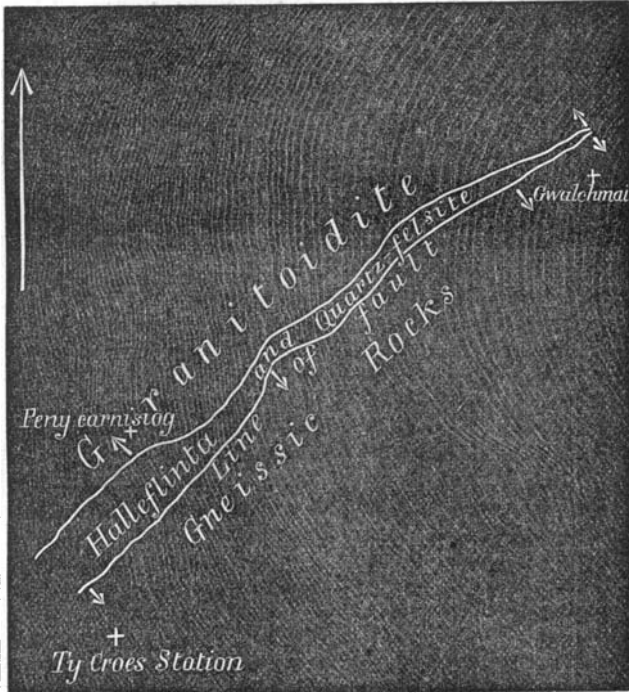
(2). At a quarter of a mile N.N.W. of (1), N.W. of "Post Office," is an exposure of grey quartzose mica-gneiss, with a high N.W. dip. This rock is continued for over a quarter of a mile to the N.W. It is well exposed at Bryn sisyr in a road section, where folia of pink felspar are very distinct. At this locality some of the schist is very quartzose. Further on, near Bryn disgwyl, the gneiss, very contorted, is exposed in quarries on both sides of the stream, and similar rock is seen in the road and fields nearly up to Y graig. The grey gneiss dips uniformly rather high to the N.W., and, if there is no repetition, it must be over 1000 feet thick.

(3). At Y graig, the dark-green gneiss comes in again, dipping N.W. at 50°. It includes, as in the Craig yr Allor district, some bands of a pinkish quartzo-felspathic rock, suggesting a transition towards the granitoid series: and contains a great deal of chlorite. It extends up to the Malldraeth fault (throwing down Ordovician shales and Carboniferous rocks), and is several hundred feet thick.

We have then two bands of dark-green gneiss, with a broad middle zone of grey gneiss, the whole dipping at a moderately high angle (say 50°) to the N.W., except at the base of the section, where the strike is N. and S., and the dip vertical or a little W. I have seen no reason to believe that there are two dark bands in the district. I am disposed to think that there is a repetition by folding, the anticlinal falling over to the east, so as to give a general westerly dip. The grey gneiss is not seen S.E. of Gaerwen windmill, and a little to the S.E., at Gaerwen station, we have chloritic schist dipping S.E. Granitoid rock is slightly exposed N.E. of Gaerwen, near Cefn du, but I was not quite sure that it was in place. Whether the repetition is by folding or faulting, or even if there is no repetition, my main conclusion is not affected, viz.:—that at Gaerwen we have a considerable thickness of grey gneiss passing up into dark gneiss, which in all respects resembles the dark gneiss of the Craig yr Allor anticlinal, and which may fairly be identified with that series. This section thus serves to bring the Pre-Dimetician gneiss of Craig yr Allor into relation with the schistose group W. of the Menai Straits, and proves that the dark gneiss is but the summit of a great gneissic series.

<sup>1</sup> It will be seen that Prof. Bonney considers this a diorite, though his determination is not very positive. There is apparent foliation in the rock, and I have left my observation to stand for what it is worth.

FIG. 3.—Plan of the group between Ty Croes and Gwalchmai.



Scale—one inch to the mile.

C.—ASSOCIATION OF VOLCANIC ROCKS WITH THE GRANITOID GROUP.

(a). *Section at Ty Croes.*—Dr. Hicks finds his Anglesey succession upon a section at Ty Croes.<sup>1</sup> Assuming the granitoid band as the base, he finds to the E. an exposure of hälleffinta, and this he places above the granitoidite, and calls “Arvonian.” Further to the E., he comes upon green schist with an easterly dip, which he regards as the summit of the series, and identifies as Pebidian. To this order I am compelled to take serious objection.

In order to ascertain the true succession, I ran a series of sections in zigzags across the three zones, for six miles on the strike to the N.E. A few of the most decisive results are here given. I take the localities from S.W. to N.E.

At Pen y carnisiog, one mile N.E. of Ty Croes, the Dimetian clearly dips to the N.W., and one band of it passes up into quartz-felsite (Note 4, p. 125), without any line of separation.

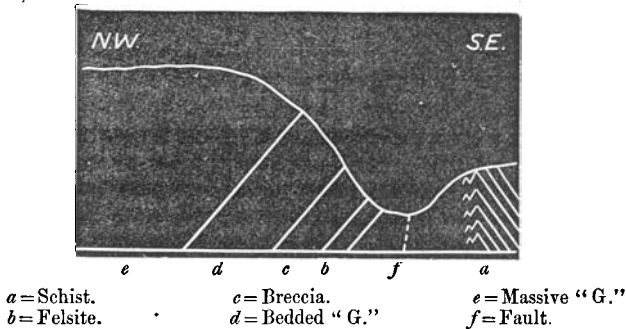
Between Ty Croes and this point, the “Arvonian” hälleffintas and quartz-felsites form a well-marked zone between the Dimetian and the schists. As the Dimetian dips to the N.W., it is difficult to see how the “Arvonian” can dip to the S.E.; and as bands of quartz-felsite of the “Arvonian” type are interstratified with the Dimetian,

<sup>1</sup> Quart. Journ. Geol. Soc. vol. xxxv. p. 302.

it is fair to conclude that the adjoining band of "Arvonian" dips in conformity with the Dimetian, and, therefore, below it.

One-third of a mile E. of Pen y carnisiog, in the "Arvonian" zone, hälléfínta, becoming rather granitoid at joint surfaces, is exposed. The "Arvonian" band is to be traced continuously for two miles further to the N.E., where, at Glanrafon, E. of Llanbeulan, it is represented by a well-marked quartz-felsite. The Dimetian and the schist (gneiss) have by this time approached much more closely.

FIG. 4.—Section two furlongs N.W. of Gwalchmai Church.



(b). *Section N. of Gwalchmai.*—One mile further to the N.E., four miles N.E. of Ty Croes, is a section which I regard as decisive of the true relations of the three groups. It occurs N. of the Holyhead Road, two furlongs N. of Gwalchmai. The "Arvonian" has almost disappeared, the Dimetian and the schistose series being separated by a hollow only twenty yards wide. To the E. of the hollow, grey gneiss is sharply contorted for two or three feet, and then it plunges to the S.E., in conformity with the uniform dip of the schist on this line of strike. To the W. of the depression, the Dimetian rises in a low, but steep, escarpment. At the base is a compact felsitic rock (Note 5, p. 126), with a horny fracture. Fine-grained granitoidite also occurs at the same level. Immediately overlying the felsite is a band of breccia, three or four feet thick. This bed is composed of horny-looking fragments, similar to the basement felsite, in a felsitic matrix (Note 6, p. 126). It clearly dips to the N.W. at a high angle, and passes gradually up into ordinary granitoidite, distinctly bedded, with the same dip; which, in its turn, passes up into the usual massive granitoid rock ("G" of the Survey), in which all traces of stratification are lost. Figs. 3 and 4 illustrate the preceding description.

This section proves that the Dimetian and the schistose group at this point are separated by a fault, for they dip steeply in opposite directions, the "Arvonian" has almost disappeared, and the schist is abruptly contorted at the junction. This dislocation undoubtedly runs to the S.W., and holds the same position in Dr. Hicks's section, throwing his "Pebidian" schists quite out of stratigraphical relation with his Dimetian and "Arvonian." That the schists are of Pebidian



age is rendered still more improbable by the fact that they are mainly gneissic. The discussion of their true age does not belong to the present paper.

In the last section, we saw, still more clearly than at Pen y carnisiog, the intimate association of volcanic rocks with the granitoid group. In further illustration of this point, and of the occurrence of hällfrinta in the Dimetian, I will call attention to two more localities.

One mile north of the last section, between Ty newydd and Tyn rhos, quartz-felsite (Note 7, p. 126) is seen at more than one point, and in each case it passes by an imperceptible transition into the ordinary granitoidite (Note 8, p. 126).

Still further to the north, between Gwyndy and Pen y bonc, a thick band of hällfrinta is exposed in a road section. This bed is towards the base of the Dimetian, since, towards Gwyndy, the latter passes down into the dark gneiss.

*Summary.*

1. The granitoid (Dimetian) rocks of Anglesey pass down into an anticlinal of dark gneiss (above) and grey gneiss (below). The gneiss is also seen in the Menai anticlinal.

2. Low down in the granitoid series are bands of felsite, hällfrinta, and felspathic breccia, which can lay no claim to the rank of a distinct group (Arvonian).

3. The schistose series at Ty Croes is brought into contact with the principal quartz-felsite and hällfrinta band by a fault, and there is, therefore, no proof, from this section, that the schists are of Peibidian age.

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VII.—NOTE ON THE MICROSCOPIC STRUCTURE OF SOME PRE-CAMBRIAN ROCKS.

By Prof. T. G. BONNEY, M.A., F.R.S., Sec. G.S.

SOME repetition may be avoided in this note by roughly grouping the specimens, which have been forwarded to me by Dr. Callaway, as (A) Felsitic Rocks, or those resembling felstones; (B) Granitoid and Gneissic Rocks; and (C) Dioritic Rocks. The numbers attached correspond with the reference-numbers in Dr. Callaway's paper. I may mention that in examining the slides I was ignorant of their bearing on the views propounded by the author, and, in some cases, of the exact locality of the specimens.

(A).—FELSITIC ROCKS (4-7).

These are compact generally light-coloured rocks, breaking with a rather sharp fracture, and weathering to a pale, whitish tint. The ground-mass of each consists chiefly of microcrystalline quartz and felspar, of very indefinite outline and arrangement, in which occur some larger grains of the same minerals, with more or less opacite and other microlithic minerals. The ground-mass of (4) exhibits a wavy graphitic or almost arborescent structure not uncommon in felsites.<sup>1</sup> The larger quartz and felspar grains are generally ragged

<sup>1</sup> Described by myself, *GEOL. MAG.* 1877, Dec. II. Vol. IV. p. 508.