21. *On the CAMBRIAN and associated ROCKS in NORTH-WEST CAERNARVONSHIRE.* By Prof. J. F. BLAKE, M.A., F.G.S. (Read December 21, 1887.)

Introduction.

THE area to which the present memoir refers has for a long time attracted the attention of geologists, partly because within it may be found the oldest portion of the Cambrian series, and therefore the supposed base of our known stratified rocks, and partly because, of late years, there has been an expectation of finding here some representatives of still older series.

The most recent observers, indeed, agree in regarding the whole of the mass coloured as porphyry between Bangor and Caernarvon, and some part of that coloured altered Cambrian, as belonging to a Pre-Cambrian epoch, and the felsite of Llyn Padarn and Moel Tryfaen they treat in the same way. There is no difference of opinion between them on this latter area, but as to the former, though all divide the mass into three parts—the mass near Caernarvon, the mass near Dinorwic, and that near Bangor,—Prof. Hughes considers all three a connected series of “beds,” Prof. Bonney regards the Caernarvon rock as very old, and the other two as connected, while Dr. Hicks regards them as representing three independent and unconformable groups. Again, Prof. Bonney and Prof. Hughes differ as to the stratigraphy near Bangor, with the effect that the former considers much more to be Pre-Cambrian than the latter does. All three views are diametrically opposed to that of the Survey, not only as to theories but as to many of the facts. Nor has the Survey given way. Prof. Ramsay, in 1881*, says the proposed changes are made on purely theoretical grounds; and Prof. A. Geikie, in 1883†, certainly accepts no change of view, on the ground that, if the Survey maps are to be corrected, it must be done in the same style as that in which they were constructed.

It will be probably admitted therefore that there is need for further observation and proof one way or the other.

I have been led personally to the study of this area from its relation to the rocks of Anglesey. If the schists of that island are really Pre-Cambrian, this fact must be proved, if possible, by tracing the base of the Cambrian, or of some older rock, across from the mainland into contact with them.

It will be well at the outset to state clearly the position to which this study has led me. I find that, though there *may* be Pre-Cambrian rocks in this area (and I am inclined, from considerations derived from other areas, to think there are), yet the evidence on the ground itself is not sufficient to justify this conclusion. In other words, the views of the Survey, exception being made of certain “convictions” with regard to metamorphism, most clearly appropi-

* Mem. Geol. Surv. vol. iii., new edition.

† Quart. Journ. Geol. Soc. vol. xxxix.

mate to the natural interpretation of the then known facts. New facts, more careful observations, and improved methods lead to a modification of these views; but the wholesale upsetting of their conclusions by later writers seems certainly to be due to a "disregard of the evidence by which the officers of the Survey" were led to adopt them.

Bangor and Caernarvon Area.

It will be well to begin our examination at Caernarvon, where matters are simplest, and where we may find a key to interpret the rest. The "field-quarry" at Twt Hill has been the scene of much controversy, and two interpretations now stand before us for choice. On the one hand, Prof. Bonney declares that the conglomerate there seen rests on the "granitoid rock," and cannot be younger than

basal Cambrian; on the other hand, the Survey make this conglomerate Ordovician, and the "porphyry" intrusive. I have examined this quarry many times, with the care that is due to its importance. (The section from S.E. to N.W. is given in fig. 2.) To my eyes the conglomerate does *not* rest on the "granitoid rock," but the porphyry cuts across the edges. A knife can be inserted into the plane of junction. The *edge* of the bed in contact (not its base) is discoloured for about half an inch, suggesting the action of heat, and the porphyry for the nearest foot from the junction-plane is of much

Fig. 3.—Plan of junction of Porphyry and Conglomerate.

finer texture, inasmuch that I at first took it for a dyke. This suggests ore rapid cooling at the edge. Again, the surface of junction is not plane or undulating, but has in one place a step in it (see fig. 3).

Again, the strike of the beds, which is nearly parallel to the surface of junction, runs right into the hill (see fig. 4). There must therefore be another great irregularity of junction, throwing the conglomerates to the south-east, between this and the new church, where they occur again, as noted by Prof. Hughes. Then there is the quarry mentioned by that author by the side of a new road at Yscuborwen*, which I have not found. Here, as at Twt Hill, the

Fig. 4.—Ground-Plan of Twt Hill.

conglomerate runs obliquely against the porphyry along a line running S.W. to N.E., and the edges of the beds are cut off by a perpendicular line. Here the conglomerate is said to dip, as at Twt, to E.S.E. At a disused quarry in a field by Tygwyn is another exposure of conglomerate and grit, here dipping at 45° to the S.S.E., the line of strike leading directly to the Menai Straits, while the porphyry is seen eight yards away towards the north.

The surface of junction, therefore, curves about in a most extraordinary manner; and seeing that the porphyry has the aspect of an intrusive rock, these observations would certainly suggest an intrusion. Nevertheless they could not have led the Survey to their conclusions, since the line is incorrectly drawn on their map. The alternative hypothesis is a rather complicated group of faults. Other considerations must be brought to bear upon the question before we can decide it.

The most important of these is the nature of the Twt-Hill rock.

* Quart. Journ. Geol. Soc. vol. xxxv. 1879.

Prof. Hughes boldly writes down "Twt-Hill beds," and speaks of "the most conspicuous divisional planes suggestive of bedding." On this I must point out that if a bedded rock could be so metamorphosed as to produce a quartz-porphyry, the first thing to disappear, as such, would be the planes of bedding; and if there are any such planes to be found in a metamorphic rock, we must look for them, not in the most conspicuous, but in the most obscure subdivisions of the rock-mass. Prof. Bonney brings the microscope to bear upon the question, and declares he can distinguish between a granite and a granitoid rock. The only points of difference that can be tested are given in a note in *Quart. Journ. Geol. Soc.* vol. xxxv. p. 306. One is that in a granitoid rock the quartzes and feldspars show more irregularity in their outlines, size, and distribution; and another that an indefinite felsitic matrix may be seen. This latter point is surely more suggestive of a porphyry, and there is little use in discussing the former, since it does not cover half the structures found in rocks of the Twt-Hill type. In various parts they put on various aspects, but it is impossible to trace the changes; they come in sporadically and die out gradually, after the manner of a granitic intrusive mass, varying its character according to its circumstances of cooling, and so merging into a quartz-porphyry. From the great similarity of the structures to those in undoubtedly intrusive masses, I conclude that the Twt-Hill rock *must* be of an intrusive character. But that it was intrusive into the conglomerate is another matter altogether. True, the edge of the conglomerate *looks* burnt in the Twt-Hill field-quarry, but under the microscope this is shown to be due only to infiltration of ferric oxide along the junction. Again, the lowest portion of the conglomerate here is very remarkable. Its quartz-fragments are quite angular, and even irregular; they are sometimes complex, as if they had come from such a rock as the neighbouring granite, and then show signs of very severe pressure. There are fragments also of quartz-schist* and other altered rocks, while the matrix is composed of secondary quartz and sericite. The rock would certainly appear to be derived from others in the immediate neighbourhood, one of which would have to be practically identical with the granite here exposed.

We must also consider what is the true age of the conglomerate. It is always spoken of as the Cambrian conglomerate, though at Twt-Hill field-quarry the succeeding rocks are scarcely exposed; but the same conglomerate is, or was, seen, by the new church, and not fifty yards away, down the sloping street, black shales are seen (fig. 4), and these are continuous for the rest of the distance to the point, quite close at hand, where Mr. Marr found Arenig fossils†. Any fault supposed to lie between Arenigs and Cambrians here is entirely hypothetical, and when the beds are traced north is found to be practically impossible. Hence it is that I conclude that this conglomerate cannot be of Cambrian, but must be of Arenig age.

* Callaway, *Geol. Mag.* 1881.

† *Quart. Journ. Geol. Soc.* vol. xxxii. 1876.

So it is coloured by the Survey, and every consideration tends to prove them right. It is at the base of the Arenig that palæontologists have suggested a break in the strata. It is the base of the Arenig that contains the overlapping conglomerates in Anglesey and Ireland*, and this is the lowest series that is most widely spread in Europe†. Hence it is nothing extraordinary that Arenig rocks should here have a conglomerate at their base, and should be associated with the porphyry (all Cambrian rocks being absent), and so it is that we find here the key to the interpretation of the district. My explanation, therefore, of the rocks near Caernarvon is as follows:—The granite is intrusive into older rocks than the Arenig, now hidden from view, though perhaps their fragments may be recognized in the conglomerate. This conglomerate once rested on the surface of these rocks, perhaps not far from the curved and bay-like line which now forms the junction with the granite; but in the upheavals of the district the union has been broken, and slippings have taken place, producing faults.

Passing now to the north-east of Caernarvon, the undulations of this base-line of the Arenig are found to be very considerable. They are traced on the Map, fig. 1, p. 272. The conglomerate almost cuts out the porphyry behind Ty-coch, where it actually dips towards it. It then passes rapidly eastward, to be found near the river-side south of Pengelli. It then apparently curves back till it runs nearly north to Careg Goch, and all the fields to the east are covered with the Ordovician shale. Then we come to the great grit-beds south-south-east of Tan-y-maes, and the conglomerate, which must be almost welded to the porphyry at the cottages, and certainly overlies it. East of this we find it thrown out to the farm at Wern, where the junction with the shale is seen. It must then be thrown east again, to curve round the farm at Cefn and undulate along the road to Gorsbach. Here we come upon a different set of underlying beds, and the conglomerate gets finer and gradually degenerates into a grit—we find this grit in the valley to the east of Gorsbach, to the south-west of Ty-mawr, and further on in a quarry near the cross roads on the western side. I have not traced it for the next $1\frac{1}{2}$ mile to the north, but find it again at Caer-hun, in quarries to the east of the road, again on the west of Pen-yr-allt, and on the east of Cae Seri, then cutting the road by the “i” in “Bryniau,” and after crossing this it rises into a good escarpment of massive grit in a wood running parallel to the road which branches off to the right. After the crossing of the next lane, and so on to the Holy-head road, very little sign of grit can be found—it may be concealed or have died out, or there may be a slight fault here. In tracing this line it will be perceived that the portion on the Bangor sheet is very accurately laid down on the map, but the part on the Caernarvon sheet has not previously been surveyed with precision. It will be seen also that the conglomerate and grit base of the series is much thicker south of Gorsbach, where it is in contact with the

* See Ramsay, Mem. Geol. Surv. vol. iii.

† See Hicks, Quart. Journ. Geol. Soc. vol. xxxi. 1875.

igneous rock, than to the north, where it abuts against the sedimentary, and is thickest in the bays of the curve, probably indicating that this curve is near the true line of deposition. The most critical part of this line is at Gorsbach, where an older conglomerate comes in, which we are only prevented from mistaking for the Arenig by carefully tracing the line on both sides and comparing the character of the rock step by step, as is done below.

We have thus marked off for our study a definite area of rocks, of which as yet we only know that they are Pre-Arenig. This area we must now examine.

The southern portion, as marked off by Prof. Bonney*, is certainly distinct from the rest, but it loses its character as we pass northwards. Thus, at Ty-coch the section shows a coarse-crystallised granite, only cracked and disturbed. As we pass into the so-called "Crug beds" of Prof. Hughes, *i. e.* at Crug Farm, we find a beautiful radiating granophyr, much cracked and filled with quartz. In the ravine west of Tan-y-maes the rock is porphyritic, with idiomorphic quartz-crystals, and a matrix partly micropegmatitic, partly mosaic; and at the extreme tongue by Tafarn-y-grisiau only the latter matrix is left, and the whole is very dirty. All these have a family likeness, and may well be considered parts of the same intrusive mass. In the side of the main road south of Dinorwic, between the two branches of the road which goes over the hill, is seen the rock into which we may suppose this porphyry intrudes. It has a dirty unstratified aspect, like an indurated mud, but really consists of irregular fragments of quartz, in a quartzose but dusty matrix, much lined and infiltrated. Immediately we cross Prof. Bonney's line and pass to the east over Dinorwic, the change in the character of the rock, as seen under the microscope, is marvellous and complete. Whether close above Dinorwic or at Pant-yr-fallan-fach, on the eastern slope of the hills, or in the valley to the east, or still further east near Tan-yr-allt, every rock is a fresh quartz-porphyry, whose ground-mass is crowded with streaming microliths, exhibiting fluxion-structure to perfection. The contrast between these and the Caernarvon group of rocks is all the more marked from the latter being in their most altered state and the former in their freshest, where they are found side by side. The subdivision, therefore, of the great mass of quartz-porphyry in this district into two distinct parts, of different ages, we owe entirely to the microscopic researches of Prof. Bonney.

I do not think that these felsites all belong to one outburst, whether as an intrusion or a flow; first, because there are varieties of the porphyry, some containing only scattered quartzes, others crowded with quartz and felspar, and some, as in the ravine near the "d" of the Tyn-y-coed, with a spherulitic matrix. Moreover, as pointed out by Prof. Hughes, there are breccia-beds, though I have only found one, running north-eastwards by Tan-yr-allt.

Probably the most important point to determine with regard to this porphyry is the nature and cause of the long tongue which is

* Quart. Journ. Geol. Soc. vol. xxxv. 1879.

drawn on the Survey Map running up from Pen-y-swintan to Friddod (see Map, fig. 1), as its distribution would suggest intrusion. This tongue is not correctly laid down in the map either of Prof. Bonney or of Prof. Hughes, but is drawn on the Survey Map with considerable accuracy.

I think, however, the probability is that it is not intrusive. In the first place the structure of the rock, as obtained at Pen-y-swintan or at the extreme end at Friddod, is not that of a dyke, which such a tongue would practically be, but the matrix shows flow-structure, and it is crowded with crystalline fragments, the rock itself not being much fractured, thus suggesting a faulted original flow. Again, as will be seen by the stratigraphy of the higher beds, the country here must be much broken up by faults, one of which, on its north-western side, might easily bring it to its present position; and lastly, it is followed in several places on the south-east side by a small conglomerate, some fragments in which, in one specimen at least, are similar in structure to the porphyry.

The beds, however, which lie between the porphyry and the Arenig grit are perhaps the most important, at all events in their relation to the rocks of Anglesey. They are divided into two areas by the fault which runs along the Bangor valley; and if we can be certain of them in one area, the stratigraphy of the other becomes more of a geological puzzle than a matter of general interest.

Fig. 5.—Plan north of Gorsbach.

Taking the eastern area, we find the first incoming of these beds just north of Gorsbach, near Llandeiniolen, where the geology is rather complicated. The ground-plan is given in fig. 5*. On the western side of the Arenig grit, which can be traced all along here, we find, next to the porphyry, a coarse quartz-felspar grit, which forms a knob at Fachell, and is scarcely to be distinguished from the porphyry, except under the microscope; next comes a band of grit, and then the dark muddy conglomerate, full of large pebbles of red felsite. Higher still is a thick mass of compact green-banded rock, such as occurs so abundantly at Bangor, and then finer material

* The Map, fig. 1, is not quite accurate here.

still, with lines curving about almost like a vitreous lava, but actually a hälleflinta. The beds above are breccias, and finally a green-banded rock again. We seem to have here, in miniature, the whole series as seen further north near Bangor, but this may not be so really. The red felsite-conglomerate, indeed, appears to die out, no trace of it appearing in the fields a little to the north as we walk across the strike of the series.

Seen under the microscope, Nos. 2, 5, 6, 7, seem all of the same type, the fragments in the several rocks differing only in size. Most of them are mineral fragments, but there are some characteristic rock fragments of a basaltic type, consisting of long transparent crystals scattered irregularly in a black opaque ground-mass. I know of no rock in this district, except in Anglesey, from which such fragments could be derived. The red felsites in No. 4 are very like those below; but one fragment I take to be an altered pumice, since it contains long cavities drawn out into fantastic shapes, and lined by a coat of inward-growing crystals; if such is its nature, it no doubt formed the surface of the felsites.

Passing north we come to the region so carefully examined by Prof. Bonney. I have, I trust, examined it with equal care, and can fully confirm the accuracy of his observations, particularly in those points in which he differs from Prof. Hughes. I have traced the quartz-felsite grit by Rhos fawr, Brithdir, round by Wern into the valley, where it curves westward round the edge of the felsite. Then the green laminated beds on the summit of the hills, and the porcellanites by Penhow, as far as the commencement of the Tairffynon lane; then the great agglomerates, jasper conglomerates, and grits at Tairffynon, and the quarry by the side of the main road, where, however, the dip is turned round, probably in the neighbourhood of the fault; then the finer beds at Perfeddgoed, which include a quantity of purple slate, near Caerhun and to the north of it; then a bluish breccia at the corner south of Cae Seri, which may be well matched at the poor-house, and another to the north, which may or may not be the same as that at Hendrewen; and finally the great hälleflintoid mass which, commencing with Mniffordd and Nant Gwtherin, forms the western slopes of Bryniau Bangor. I have nothing to add in this region to the proofs adduced by Prof. Bonney in support of his statements of the succession, which, to those who have examined the ground, should be perfectly convincing. (See the Map, fig. 1.)

Here, however, we part company. There lies to the north a conglomerate of large stones which, for some reason I have never discovered, has been called by everyone in latter days the basal Cambrian conglomerate. Now the last few of the grits having had a pretty persistent strike of N.N.W., we find in the fields by Nant Gwtherin another coarse grit, its strike still N.N.W. This seems to have been identified with the so-called "Cambrian conglomerate" by Prof. Hughes; but a careful survey will show that this cannot be right, for we can follow this grit for some distance along its strike, and find to the east of it, *i. e.* above it,

in the sequence, some more hälleflintoid rock (well shown in a quarry by the roadside), and we must go to the east again to find the conglomerate of large stones in the nearest spot of the adjacent field. This can scarcely be brought about by a fault, since the Arenig is undisturbed; and moreover the coarse grit does not resemble the conglomerate, but resembles more closely a grit seen where its continuation should be, to the west of the conglomerate on Bryniau Bangor. The great conglomerate appears to die out on the south, as conglomerates do; but we may trace it from a knob at about the "n" of Bryniau, in a north-north-west direction, to the west of, and nearly parallel to, the road; and this strike leads exactly to the spot where it is found in the road, as noticed by Prof. Hughes. It is therefore strictly conformable to the underlying beds. It is just near its southern termination, but on the opposite side of the road, that the escarpment of Arenig grit is seen striking N.N.E., in other words making an angle of 45° between the two. There is therefore no conformity with the overlying beds. Moreover, if the great conglomerate were the base of a new series, the beds above ought to be decidedly different. There are certainly a few purple beds in the road, but so there are far away to the south; but the main mass is difficult to distinguish from the hälleflinta below—so difficult, it appears, that Prof. Bonney, by curving round the conglomerate, has made beds, which really lie *above* it, appear to lie *below*, thereby unconsciously testifying to their identity.

I can therefore regard this so-called *basal* Cambrian conglomerate as nothing else than another and the most remarkable of the series of conglomerates which characterize these "Bangor beds." It is clear, then, that above the porphyry we have an ascending conformable series of conglomerates, grits, and more or less banded hälleflintas, alternating with each other and overlapped unconformably along their eastern side by the Arenig grit.

I have also carefully examined the country on the western side of the fault, but I am afraid it is more or less labour lost; we learn nothing further as to the succession, and cannot hope to tell whether a rock is conformable or not, especially when, like the great conglomerate, it changes its strike by more than 45° in the course of its $1\frac{1}{2}$ mile run. But I am not in the least certain that this is on the same horizon as the great conglomerate on the other side of the valley. To begin with, the pebbles are not the same, those on the east being far more quartzose; but the rock is most like *one* of the beds at Tairffynon and the dark conglomerate of Fachell, a correlation made by Prof. Hughes. It would require the least number of faults to bring this about, and the beds actually seen below it are similar to those which occur below the Tairffynon conglomerate, while the beds above are more comparable on the two sides of the valley than they would be if we identified it with the conglomerate of Bryniau Bangor. I think the most *probable* stratigraphy here would be to draw a line of fault with an upthrow on the east, making a very small angle with the main fault, and running from near the "Inn," opposite Treborth, to beyond the Baths at Garth,

thus bounding the felsite on the west, and running through the corner of the road where the great conglomerate changes its strike. A small fault *does* come out on the shore between the Baths and the Ferry. Thus the general strike of the beds on the east side of this fault would be to the east of north, instead of to the west of north, as on the other side of Bangor valley. But if my view be correct, all this is a matter of little consequence. The puzzle is to account for the very large pebbles of felsite and other volcanic products when the felsite near at hand must have been covered up by earlier deposits, and there is none other near to choose from.

Thus the Pre-Arenig rocks near Bangor form one indivisible series, but what is their age? Are they also Pre-Cambrian? The supposed proof of this has rested on the *assumption* of a basal Cambrian conglomerate, and the assumption is not justified. With Prof. Ramsay the only question was between what we now call Upper or Lower Cambrian, *i. e.* between "*a*" and "*b*," and he concluded, from a comparison of these rocks with others in Glyn-lifon Park, that they were Cambrian rather than Lingula-flags. Another reason that led him to this conclusion was the similarity of the conglomerates near Bangor to those near Llanberis, which are undoubtedly Cambrian. Any difference between these was accounted for by metamorphism. We can, however, dispense with much metamorphism, and yet compare these rocks with Cambrians. There is little to choose, microscopically or otherwise, between some of the rocks near Gorsbach and some near Llyn Padarn, nor between some varieties near Bangor and the rocks in the heart of the Cambrian near Llandwrog, nor between the grits north of Perfeddgoed and some west of Dinas Dinorwic. The included fragments may be somewhat different, but they are exactly the same type of rock. The great peculiarities of these Bangor beds are their great total thickness without reaching the great workable slates, and the presence of numerous and various conglomerates. They are called volcanic, but they are arranged in beds after the manner of sub-aqueous deposits, and can only be said to be volcanic as having been derived from the denudation of volcanic products. They are, of course, of later date than the volcanic eruption whose remains are seen in the porphyries. Thus their general features attach them to the Cambrian, and their peculiarities are what we might expect at the base of such a series. Is not the cause of any minor differences from other Cambrian rocks simply that we never see the base of the Cambrian elsewhere in North Wales?

This opens up another question, and forces us to the study of the rocks by Llyn Padarn, since these are supposed to represent the basal Cambrian, and to lie upon a Pre-Cambrian axis.

Llyn Padarn and Moel Tryfaen.

The great conglomerates which lie on the east of the masses of porphyry, on either side of Llyn Padarn, are considered by every one to be the base-bed of the Cambrian. According to Prof. Ramsay, as Q. J. G. S. No. 174.

I understand him, the conglomerates first lay on the hidden land from whose denudation they are derived. Then came an eruption of porphyry, which crept between the two and absorbed into its substance the lower part of the conglomerate. According to Prof. Bonney and Dr. Hicks, the porphyry was poured out as a lava, and the conglomerate was derived from its denudation. The proofs of this latter view are numerous. First, there are the abundant pebbles of felsite found in the conglomerate, which are certainly like the porphyry below; and it seems unnecessarily going out of the way when Prof. Ramsay says they are like some Bala felsites. Another argument may be derived from the way in which these conglomerates cling to the porphyries all along their range. They are seen in contact on Clegyr and on the south of Llyn Padarn, and though Dr. Hicks *supposes* there are some schists between them at Moel Tryfaen, his dark porphyritic-looking rock, which comes in the adit next the felsite, has been recognized by Prof. Bonney as the conglomerate itself; and in a small cutting of the slate railway on the west-south-west of the summit of the hill, the conglomerate is actually seen side by side with the felsite, neither passing into it, as supposed by Prof. Ramsay, nor unconformable to it, since there is no bedding in the felsite.

Furthermore Prof. Bonney has pointed out the flow-structure in the porphyry. I may add that, as observed by Prof. Hughes, to the west of Clegyr, and in immediate contact with the conglomerate, there are great masses of agglomerate, and these are repeated in connexion with another flow at a lower level, having a nose of breccia at its termination near Llys Dinorwic. We can scarcely, therefore, hesitate to admit, in the light of such observations, that these are really, practically at least, subaerial flows, and that the conglomerates have been derived in part from their denudation.

But the next question is, what is the age of the porphyry? in other words, what did it flow upon? Prof. Bonney and Dr. Hicks do not seem to have inquired into this. They take it to be Pre-Cambrian, and are apparently hopeless of finding any base or floor for it. If such a floor is to be found, it must be on the western side, since the conglomerate lies to the east; but here there is a great mass of Cambrian strata, and it is the relation of the felsite to these which we must examine. In some parts the junction is marked as a fault, but in the rest it is not. On examining the ground we soon find that the western boundary is for the greater part hypothetical, as it is confessed to be in the explanatory memoir*. The ground is covered by drift, and no junction can generally be seen. The only exception to this is on the north-east side of the river Rothell, where the drift is absent. This, then, is the crucial spot. If there is a fault here, our question must remain unanswered; but if there is not, and the felsite is older than this western Cambrian, as well as the eastern conglomerate, then the beds on the western margin must turn up and be found lying upon, or dipping away from it, and so

* Mem. Geol. Surv. vol. iii. 1866.

Prof. Ramsay and, after him, Dr. Hicks draw the section, though they introduce a fault as well.

But is this so? On the north-west side of the felsite there is a low alluvial valley, about 200 yards wide. On the opposite side, quite close to the valley, there are exposures of rock; but it is *not* a conglomerate, but ordinary fine slates, with vertical cleavage, but dipping towards the felsite at an angle of about 20° . This is suggestive, but affords no certain datum; our only chance is on the edge of the felsite itself. It is ill founding a determination on one section, but in this case a single proof could scarcely be more decisive. On the west side of the road from the bridge to Bryn Efail, and exactly on the letter "E" of that word in the map, there is a quarry in the felsite, which here shows a precipitous face towards the valley. The plan of this quarry is shown in fig. 6. The edge of the felsite

Fig. 6.—*Plan of Quarry at Bryn Efail.*

is ragged and irregular, but perfectly clean. In the centre of the quarry it runs against a boss of greenstone, and cuts it into promontories and twisting tongues. At the sides of this the junction is, for the most part, with a vertical bed of slate, which is followed on the west by a bed of grit, with which also the felsite occasionally comes in contact. The strike of these beds is nearly parallel to that of the Cambrians just noticed. The felsite is so welded with the slate that it is easy to obtain a junction specimen, and two such have been examined. In one the line of junction is perfectly straight. The felsite shows the quartz-crystals somewhat broken and exhibiting signs of pressure, and the ground-mass is crypto-crystalline and of varying coarseness; the whole is singularly like the band at the edge of the Twt-Hill mass in the Field-quarry, and I have no doubt they were formed under similar circumstances. Towards the junction both felsite and slate are infused with ferric oxide, which produces a coloured band in the slate of about $\frac{1}{8}$ inch in width. In the slate are developed abundant crystals of chiascolite, to judge from their long shape, their rhombic cross-section, and their dark line down the centre, and their being broken up into an infinitude of small low-polarizing crystals, which refuse to extinguish as a whole. There are also a number of small high-polarizing crystals which I cannot identify. In other words, the slate is altered by contact with the felsite. The same phenomena are

observable in the other specimen, where the felsite runs in veins into the slate.

In the road outside the quarry, beneath some cottages, there are again phenomena which point to the same conclusion (see fig. 7). In the mass of rock, on which a brick wall is built, are seen the felsite and baked slate running into each other in a way which proves intrusion, in this case, of course, on the part of the felsite.

Fig. 7.—Section in Road near Bryn Efail.

This spot is so important in its teaching as to the age of the felsite, that I can only suppose that it has escaped the attention of previous observers. It provides a crucial test, and thus a decisive proof, that this great flow of acid lava was, like the 99 per cent. of which Prof. Sedgwick speaks*, contemporaneous with the Cambrian rocks amongst which it is found. The Cambrians to the west are of earlier, and those to the east of later date than this. The question being thus apparently settled, it is necessary to see how this conclusion fits with other facts that may be observed in the neighbourhood. In the first place, the conglomerates ought to contain not only felsites, but also fragments of the Cambrian rocks to the west. At Clegyr, where the top of the felsite is an agglomerate of felsitic fragments (and nothing would be easier than to round them into pebbles), the conglomerate is mostly, though not entirely, made of such stones. But at Moel Tryfaen, where the top of the felsite, for some reason, is clean, the majority are slate. On this, Prof. Ramsay says†, “the pebbles of purple slate resemble those of the very strata amidst which they are found; the quartz-rock and jaspers resemble some of the metamorphic rocks of Anglesey.” It is remarkable that Dr. Hicks‡, who thinks this conglomerate is derived from Pre-Cambrian rocks alone, omits all mention of the purple slates, and enumerates only “quartz, quartz-felsites, porphyritic rocks, and schists.” Now these fragments of slate are large and scarcely

* Quart. Journ. Geol. Soc. vol. iii. 1847.

† *Ibid.* vol. xxxiv. 1878.

‡ *Ibid.* vol ix. 1853.

rounded, and cannot have come from far; and no such *large* slate-fragments, as far as I have been able to discover, are to be found in any of the conglomerates of Bangor, which must be nearer to their source if they come from Anglesey. The quartz- and jasper-pebbles at Moel Tryfaen, on the contrary, are rounded and not so large; and when we remember the large quartz-pebbles at Bangor and the jasper-fragments at Tairffynon, and also at Llandwrog, we may well believe that these pebbles have come from their original home by two stages, and that their previous resting-place was in the earlier Cambrian conglomerates. It is true that the majority of these "slates" are so indurated and compact that they are more comparable to the lower beds near Bangor, which are regarded by Dr. Hicks as Pre-Cambrian; but among them there is a minority showing that peculiar banding of purple and green which can scarcely be matched in any bed near Bangor, but only further up the series. Thus, in any case the pebbles are consonant with, and they may be considered to confirm the Mid-Cambrian age of, the conglomerate, and therefore the possibly still Cambrian age of the Llyn-Padarn and Moel-Tryfaen porphyry. But on the ground of a supposed unconformity, a long interval is claimed to have elapsed between the two rocks: and this idea is likely to militate against the view of these porphyries and their companions being mere incidents in the Cambrian succession. As, however, the underlying beds are volcanic breccias, they are naturally irregular, and I will therefore quote the words of Prof. Green in describing them:—"The unconformity . . . does not necessarily indicate any great difference in age . . . The breccias are of volcanic origin, and the irregular and restricted upheavals and disturbances, which are always liable to occur where volcanic activity is going on, are quite competent to bring about unconformities quite as marked as those of the present section." I may quote also the words of Prof. Hughes, which exactly express my view of the matter:—"In the Llyn-Padarn section the fragments in the agglomerates are much rounded, so as to suggest that towards the close of the period of volcanic activity a larger and larger proportion of the volcanic ejectamenta got worked up by the action of the sea, until, at a subsequent (but perhaps not long subsequent) period, they were all sea-washed and rolled, forming, with the waste of rocky shores, the coarse conglomerate which we have taken for the base of the Cambrian." These words are just as true, whether we take the conglomerate as the base of the Cambrian, or as a bed some distance up in the series.

But, again, if the beds, as we find them, are approximately in chronological order, the series to the west of the porphyry ought to be distinct from the series on the east. As to this there is a difference that must at once strike every one; on the west side there is not that great mass of workable slate which is so remarkable on the east, and which clings so closely to this old porphyry, coming in with it at Penrhyn and going out with it at Nant-y-llef. To go further it is necessary to enter into some detailed stratigraphy, especially as I regret to find myself in disaccord with the distinct words

of Prof. Ramsay, who says* that the beds "on the west of the porphyry are the same in number, arrangement, and lithological character as those on the east."

This point, therefore, must be carefully considered. Prof. Ramsay draws a section from Dinas Dinorwic to Clegyr (fig. 55), in which the two lowest members of the Cambrian undulate at low angles for two miles from Dinas as far as Bryn Efail, where they are cut off by a fault, and these two lowest members are also found on the top of Clegyr. In spite of the undulations, however, he has to make the western portion seven times as thick as the eastern to make a section at all. Then we have seen that the beds nearest Bryn Efail do not dip west, and that there is no fault. At Dinas Dinorwic Dr. Hicks says he has found large one-inch pebbles in a conglomerate. This is not mentioned by Prof. Ramsay, and after twice knocking all over the hill, I failed to find it. If it be there, it is followed by a tough grit, almost like a felsstone, which forms the mass of the hill, and must be of great thickness. There is a dip of 70° inserted on the map. Then at Tyn-y-cleout we have a mass of purple-banded slate, not unlike the Bangor series, which appears to continue a long way. Then we reach the mass of Dinas Mawr, a lofty hill composed of coarse jasper-grit, most like that near Brithdir; to the east of this we have purple slates again, with interbedded grits, gently undulating for the first time, but on the whole not turning up again. Such is the western series (see fig. 8); the eastern has been described by Prof. Bonney. On the railway-section north-east of Llyn Padarn he supposes a fault between the porphyry and the conglomerate; but there is really none; the two may be traced clinging to one another in an irregular line up on to the western slope of Clegyr. On the railway the conglomerate is not so distinct from the agglomerate as above (perhaps there is no agglomerate here), and under the low anticlinal further east there is only left a fissile breccia to represent it. After a greenstone-dyke comes a remarkable series of beds, namely, banded hllefinta, as seen at Bangor, perhaps 50 feet, becoming more slaty at the top, then a remarkable false-bedded band, the lines being made of purple grains and the matrix felsite dust. This is so compacted that it looks quite like a felsite. It is intensely cleaved across the bedding and false-bedding. This is followed by a one-foot band of purple-slate conglomerate pulled out into lenticules, and interseculating with finer material. Then are seen for 100 ft. greenish slates, getting purple by degrees, and often containing another thin band of cleaved felsite-grit, and then the purple slate, which, after an interrupting fold, is seen to be the base of the great roofing-slates. There is not, therefore, really much between the conglomerate and the roofing-slate, and when we compare it with the western beds, the series could not well be more distinct, considering that they are both Cambrian. It is interesting also to note that hllefinta is not peculiar to the rocks near Bangor, but is rather in relation, as it appears, with a previous volcanic outburst.

* Mem. Geol. Surv. vol. iii. 1886, p. 154.

From this examination I cannot understand on what Prof. Ramsay's statement is based. I fear it cannot be maintained. Much of the mapping, too, here is acknowledged to be hypothetical, and leads, as I conceive, to too great importance being attached to these felsites. Thus the porphyry west of Clegyr, which itself consists of two different flows, separated here and there by deposits of slate*, is never seen to cross the road at Llanbabo, and its occurrence beyond, together with the fault, is entirely conjectural, as the whole country is covered deeply in drift, a circumstance in itself suggestive that the underlying rock is not likely to be so hard a rock as felsite. Then the felsite of Moel Gronw is not apparently connected with the former, nor can it be traced beyond the road called Cefn-y-waun. The basal conglomerate does not wrap round it, but forms a band clinging to the east of Clegyr only, and leaving Moel Gronw some distance further east. The Moel-Gronw felsite is thus a later outburst, which is separated from the purple slate above by only a band of grit, which *perhaps* is represented in the form of a thin band of conglomerate seen in the railway at a higher level than the great one. The limits of the felsite, as actually seen, are also very much smaller than drawn on the south-west. The line is carried out as far west as Glanrafon, on the Gorfai River, where there is an exposure of rocks in the deep river-gorge; but these are quite different from those of Moel Swtan, which is the nearest exposure of the true Llanberis

* See Bonney, Quart. Journ. Geol. Soc. vol. xxxv. p. 312.

felsite. There are three varieties, close together and of small size, probably insignificant intrusions. Then the mapping round Moel Tryfaen is shown by the adit and cutting on that hill to be wrong. There can be no fault between the conglomerate and the slate. The great mass of felsite represented as occurring to the west is all under drift-covered country, while the conglomerate wraps round the felsite between Moel Tryfaen and Pen-y-groes. These corrections would curtail the importance of the porphyry and make a great fault unnecessary.

Thus the Cambrian age of this mass of porphyry, as determined by the nature of its under and its upper surface, is consonant with, and confirmed by, the other tests to which the conclusion can be submitted.

We must now apply this determination to the question of the age of the rocks near Bangor. Since the conglomerates of Llyn Padarn and Moel Tryfaen are *not* the base of the Cambrian, there is no reason why they should correspond with any particular band in the series at Bangor, either towards the top or at the bottom. But if these Padarn conglomerates are not the base, where is it? *Nowhere* in this particular area. We go downwards as we go westwards till interrupted by a pair of trough faults, letting down the Ordovician. When we get over this and come upon the older beds again, what should they be but the continuations westward of the Cambrian series? There is scarcely a bed amongst them that we cannot match somewhere or other in the higher parts of the series, though on a smaller scale. Considering the lateral changes that may take place in rocks, and the frequent dying-out of conglomerates, we cannot safely say that all the Bangor beds underlie all those from Dinas Dinorwic east: the correlation of bed with bed, or the proof of their independence, if it were thought of importance, would require a further long series of stratigraphical researches. All we can say is, that we see to the south of Bangor the base of the Cambrian down to a great felsite lava-flow; but whether this, like that at Llyn Padarn, was contemporaneous and followed below by earlier deposits still, or was erupted at a date that may be fairly separated from the Cambrian period, there is not enough evidence in this district to show.

Conclusions.

The results of the examination in the areas between Bangor and Caernarvon, and from Llyn Padarn to Moel Tryfaen, of the rocks which are found within them, are not very confirmatory of the views of recent observers, but lead us back, with certain important modifications, to the earlier teachings of the Survey on the district. They may be summarized as follows:—

1. In the Bangor to Caernarvon area: three distinct conglomerates have been confounded together. The only one which, by its unconformable overlap, sets an upper limit to the age of the rocks below

is of Arenig, *i. e.* of Ordovician age, and can only be called Cambrian by the misleading use of the term, which embraces all rocks up to the Bala series.

2. The rocks of the southern and central portion are essentially of igneous origin.

3. These may clearly be distinguished into two groups, of which the southern is probably intrusive, and the northern is certainly eruptive.

4. There is an interval of time between their production; but how great an interval, there is no evidence to show. That the southern mass is of later date than the Arenig, and intrusive into it, is a tenable hypothesis; but that it is of earlier date and overlain by the northern portion, is far more probable.

5. The Bangor beds are derived from the denudation of the volcanic series and of rocks which may have been associated with it.

6. These beds contain a series of conformable conglomerates, of which the great conglomerates near Bangor are members.

7. They are the continuation downwards of the Cambrian rocks seen to the east, and have not undergone very serious alteration compared with the latter.

8. The porphyries of Llyn Padarn and Moel Tryfaen are contemporaneous lava-flows in the midst of the Cambrian series, the overlying conglomerates being derived from them and from the Cambrian sedimentary rocks to the west.

And hence, finally, there is no certain proof of there being any Pre-Cambrian rocks in the whole district, though there is great probability that the rock near Caernarvon belongs to a distinct epoch anterior to the Cambrian.

I may add that nothing here observed invalidates former conclusions as to the essential independence of the group which lies below the true basal Cambrian conglomerate in the St. David's district. That group does not bear sufficient resemblance to the series in north-west Caernarvonshire to justify their correlation, and the unconformity there observed is of a totally different order, and comparable rather to the overlap of the Ordovician beds in this district.

DISCUSSION.

Prof. T. M^cK. HUGHES said the question was too large and intricate to discuss thoroughly at so late an hour. His reading of the stratigraphy of the Twt-Hill quarry and of the sections near Llandeiniolen and Bangor differed altogether from that of Prof. Blake, whose correlation of the various conglomerates appeared very doubtful.

Dr. HICKS felt the same difficulty. In his opinion Prof. Blake had misunderstood the beds and had not sufficiently considered the effects produced by the faults. The pebbles of felsite in the Cambrian conglomerates showed a cleavage produced before they were broken

from the parent rock. At Llyn Padarn the Cambrian conglomerates rest on the cleaved edges of the underlying felsitic rocks, therefore the latter cannot be intrusive in the Cambrian.

Prof. BLAKE, in reply, said he had the advantage of having read Prof. Hughes's and Dr. Hicks's papers. He showed that if Prof. Hughes's view of the Twt-Hill quarry-section were correct, the change would not be opposed to his (Prof. Blake's) contention. Some other objections were answered in detail.