27. *On the Rocks between the QUARTZ-FELSITE and the CAMBRIAN SERIES in the Neighbourhood of BANGOR.* By T. G. BONNEY, M.A., F.R.S., Sec. G.S., Professor of Geology in University College, London, and Fellow of St. John's College, Cambridge. (Read May 23, 1883.)

THIS district has already been the subject of papers published in the Quarterly Journal of the Society *. The authors of these agree in accepting the coarse conglomerate exposed (for instance) on the upper part of the hill pierced by the eastern tunnel of the railway near Bangor, as the base of the Cambrian; but there is still some diversity of opinion as to the relations and extent of the subjacent series. The views on the latter point will be found respectively expressed in papers by myself and Professor Hughes in vol. xxxv.; and since the publication of the latter I have four times revisited the district, leaving, I believe, but few exposures of the rock unexamined (except such as may occur unknown to me in private grounds). As I adhere to my original opinion as to the sequence of the beds, I now ask leave to state as briefly as possible the additional evidence which I have succeeded in gathering. At the same time I am glad to take this opportunity of frankly admitting that in the part of his paper which treated of the relations of the conglomerate and the granitoid rock at Twt Hill I was wrong, and Prof. Hughes was substantially right. Repeated examination of the district and of specimens under the microscope has convinced me that, notwithstanding the apparent passage of the one into the other, the conglomerate is much later in date than the granitoid series. Whether it be of the same date as the Cambrian conglomerate in the Bangor area is, I think, at present by no means certain. I can hardly regret the mistake, for in the correction of it (as related in Geological Magazine, decade 2, vol. ix. p. 18) I have learned much; and that I made it at all was, I believe, due to the last lingering impressions of the instruction which I had found in the writings of those whose teaching was regarded some dozen years ago as authoritative. Had I then commenced my petrological studies in a spirit of absolute scepticism, I should have been saved much time and some errors.

The main point, however, at issue between myself and Professor Hughes with regard to the Bangor district is the following:—I had described in the district south of the fault, which runs nearly along the line of the road from Bangor to Caernarvon, a series of rocks in which occurred at least four well-marked beds of breccia or conglomerate, which appeared to me to be so distinct that I could only conclude that they indicated horizons, and that the succession as a whole was an ascending one. Three of these, unless I misunder-

* Vol. xxxiv. pp. 137 & 147, and vol. xxxv. pp. 309 & 682.

stand him—all, in short, but the greenish breccia which occurs on Bangor mountain, Professor Hughes considers to be only the Cambrian conglomerate repeated by faulting, so that the series separating the quartz felsites from the conglomerate at the base of the Cambrian is reduced to the above-named green breccias and the gritty slates in association with them—that is to say, rather less than one half of the thickness which I should assign to it. Of the faults which are needed for this repetition I have not been able to find satisfactory evidence in the field. The principal argument for their existence appears to be the hypothesis that one conglomerate is equivalent to another, an argument which it is obvious stands or falls with the hypothesis.

I commence, then, my revision of the district with the eastern edge of the great mass of quartz felsite near Brithdir Farm. In apparent succession to this (I could not discover any evidence for the intermediate band of slate inserted on Prof. Hughes's map) we find (on both sides of the lane which mounts in a S.S.W. direction from the main road along the bed of the valley) a grit mainly (if not wholly) composed of quartz, felspar, and felsite fragments, occasionally becoming conglomeratic and containing pebbles of felsite, which can be traced pretty continuously round the brow of the hill near Wern, until, on its northern scarp, we again come to the main mass of felsite. We pick it up by the high road in the valley below (on the other side of the fault), still in apparent sequence with the felsite; we follow it by Taffarn newydd to Beulah Chapel, where it is still in sequence, and find it thus in the field-way leading to a farm opposite to the lodge of Gorphwysfa, and it is seen for the last time just above the west entrance of the western tunnel. This felsite grit, the constituents of which certainly seem to have been derived mainly, if not wholly, from the adjacent felsite, appears to be succeeded near the turning to Wern Farm by greenish grits and a little purplish slate, over which comes a rock rather like that at Tairffynnon quarry, varying from a green grit with reddish spots to a coarsish breccia or conglomerate more like that in the above quarry. It is also worth notice that about 80 yards to the east of the above-named tunnel-entrance is a small outcrop of a similar rock, and many fragments are to be seen in a spoil-bank consisting of materials which have doubtless been obtained in making the tunnel.

It seems, then, not unreasonable to suppose that this grit and conglomerate, which, for purposes of reference, I will call A, thus seen at intervals between two points about $1\frac{3}{4}$ mile apart in a straight line, is in true sequence with the felsite, and is not brought by a fault into its present position.

The next breccia which I have described (we will call it B) is well exposed in a pit in the wood at Tairffynnon, and some overlying beds of a more slaty character are seen in the lane. As mentioned in my paper in the 'Geological Magazine,' I have since traced it on the upper parts of the ridge to the N.N.W. (roughly) of that pit; and in 1880 I found that a new pit opened by the Caernarvon road

had exposed a similar rock almost exactly at the spot where I had anticipated it would occur. At this place the dip appears to be rather to the N. of E., perhaps E.N.E., while the dips about Tairffynnon are generally about E.S.E., a twist towards the northward of which we have other indications near this fault. This breccia, then, retaining its characteristic aspect, has now been traced for above half a mile.

The peculiar breccia (C), containing elongated fragments of purple slate with smaller bits of felsite, had been traced prior to 1880 from near Tyddn Dreiniog to Cae Seri; and I had stated that I expected it would occur in the neighbourhood of the Poorhouse. In that year I observed a pit (perhaps 200 yards to the south-east of the building, which had been overlooked at my former visit) in which I found a rock impossible to distinguish from the Cae-Seri rock. Here also the dip (difficult to ascertain) seemed to be about N.E., a direction which is confirmed by other observations in greenish grits and slates in the neighbourhood.

During a brief visit in 1882 I found traces of a similar rock in the interval between this pit and Cae Seri. This peculiar breccia (C) has now been traced for a distance of full a mile as the crow flies.

In succession to this comes, I believe, the greenish-grey felsitic grit of the Hendrewen quarry, in which are occasional well-rolled pebbles of similar-coloured felsite. Under the microscope it is seen to consist of fragments (generally rounded) of quartz, felspar, and an acid lava. The last commonly show more or less of a fluidal structure, and, examined with polarized light, are crypto-crystalline; but two or three are crowded with elongated crystallites of felspar, as may be seen in many trachytes. The materials are rather more decomposed than is usual in the other breccias. There is also one rounded fragment of a quartz grit. The grit described from the quarry by the white cottages west of Minffordd (I think the spot called Nant Gwtherin on the map) has some resemblance to this from Hendrewen, and is probably higher up in the same series.

So far as I can gather from Professor Hughes's map and paper (vol. xxxv. p. 682), he regards the quarries at Hendrewen and at the back of the Poorhouse as both in Cambrian conglomerate (pp. 690, 692), but the one near Nant Gwtherin and the rock of Cae Seri as part of the Bangor beds.

The district between B and C is one not easy to unravel. I have zigzagged over it, and found most of the outcrops to be greenish gritty rocks, sometimes pink-spotted; and near Brynllwyd Farm are conglomerates, one of which contains some fragments of purple slate like that in the Cae-Seri breccia. At this place (*e.g.* near Careg Hwfa) Professor Hughes again brings in the Cambrian conglomerate. I cannot, however, say that the rock closely resembles any of the admitted exposures of the latter, though it has something in common with both B and C. Hence I think it more natural to regard these conglomeratic beds as merely local intercalations in the intervening zone.

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Fig. 1.—*Sketch Section to illustrate the General Succession of the Beds as maintained by the Author. (Scale 2 inches to 1 mile.)*

For explanation, see Map, fig. 2.

Fig. 2.—*Sketch Map of Bangor district, founded on the Geological Survey Map, from which the Faults (except the hypothetical one N.W. of the Caernarvon Road) are taken. (Scale 1 inch to 1 mile.)*

The black lines indicate faults.

The Cambrian conglomerate (D), above the admitted Bangor Series on the hill pierced by the tunnel east of the station, is as different as it well can be from B and C, but somewhat resembles A; from which, however, it differs in containing numerous pebbles of quartz and quartzite (exceeding in number those of felsite), and in possessing a more sandy matrix.

If, then, A, B, C, and D are the same rock, we must suppose:—

(1) That whenever there is an exposure along the edge of the quartz felsite for more than $1\frac{1}{4}$ mile, either the whole Bangor series is overlapped by the Cambrian conglomerate, or the latter by faulting is exactly fitted onto the igneous rock, and is composed of materials wholly, or almost wholly, derived from it.

(2) That in the space of about $1\frac{1}{4}$ mile, measured at an angle of about 45° with the general strike, the Cambrian conglomerate changes from a rock consisting almost wholly of felsite to the mixed but different and more brecciated types of B and C, and then returns to the more similar bed D, with its well-rolled pebbles.

The annexed section (fig. 1) represents diagrammatically the result of the observations described in the above remarks; and when we regard the general agreement in dips and the lithological character of the rocks, it seems more natural to consider the whole an ascending series, and to extend the Bangor beds of Professor Hughes down to the quartz felsites. On the map (fig. 2) I have endeavoured to record the same observations as well as can be done on one of so small a scale.

As regards the district between the Menai Strait and the fault running S.W. from Bangor down the valley, which has frequently been mentioned above, I have little to add, notwithstanding repeated examination, to what I have incorporated in the foregoing remarks. Above the conglomeratic grits therein mentioned, and the great conglomerate extending from the shore by Gored Gith to the eastern entrance of the west tunnel, we find nothing but greenish or purplish slaty beds, occasionally slightly gritty, which perhaps generally agree better lithologically with the normal Cambrian than with these underlying beds; but the prevalent dip appears to carry them under the conglomerate. This same conglomerate, so well exposed for a considerable distance, as traced by Professor Hughes (over half a mile), is a little perplexing. Felsite forms a much larger proportion of its materials than is the case in the conglomerate pierced by the eastern tunnel; and it seems intermediate between this and the one near Gorphwysfa*. Still, as it retains its character so uniformly for so great a distance, and terminates within less than half a mile of the Poorhouse quarry, we can hardly, I think, regard it as on the same horizon as the breccia (C), or, what would be simpler, identify it with that in the Hen-

* This resemblance, and the occurrence of a patch of conglomerate between the two, caused the perplexity about the position of that near Gorphwysfa, mentioned in Geol. Mag. decade 2, vol. vii. p. 302, which was not removed till 1880.

drawen pit *. It does not, however, appear to me that the quartz and jasper grit and conglomerate west of the pier at Garth can be associated with the above. The following extract from my notebook explains the sequence of the rocks on this part of the shore:—“W. of the new slate-pier are dark beds, resembling in the upper part those on the other side of the pier mapped as Arenig, and in the lower becoming gritty and containing bands of small pebbles only a few inches thick, the general dip being 10° – 20° S.E. Then we come to green and purple bastard slates, faulted down, and in places much disturbed in consequence, the prevalent dip (not easy to ascertain) being apparently 40° S.W. Just west of the old slate-pier is a bank of screes of bastard slate and fine grit, among which I found bits of green breccia, reminding me of those seen above Bryniau, though in a much finer condition. About 150 yards east of the bathing-place green-banded argillites dip at about 40° S.E., and slaty beds then continue to the bathing-house, when the conglomerate sets in, which, so far as one can ascertain, has an easterly dip.” If these observations are correct, it is evident the whole district is completely smashed up by faults.

I have, however, found a rock, seemingly just on the north side of the main fault in the Caernarvon-road valley (in a quarry north of the crossing of the road from Maesmawr to Brithdir), bearing some resemblance macroscopically and microscopically to that at Tairffynnon; and in a pit at the back of Caemabadden Farm is a greenish grit, which, in its coarser parts, contains bits of green slate and red felsite, and may belong to the upper part of the zone between B and C. If I am correct in the position I assign to the bed A, then the whole series north of the fault has a strike rather to the east of N.N.E.; so that all the upper part of the Bangor series would be cut out by the faults which bring down the very Cambrian-looking beds above the cross roads at Pen-y-chwintain.

Until the outcrops can be laid down on a map on the 6-inch scale, it will be hopeless to come to any satisfactory conclusion in this complicated district north of the fault, and not easy to bring into complete order that on the southern side. I trust, however, that I have succeeded in showing that my original reading is the more simple explanation of the facts observed both in the field and with the microscope—namely, that there is a general ascending succession in this district, and that under the name of the Bangor Beds we must include not only the green gritty slates and breccias assigned to them by Professor Hughes, but also a large lower group extending from A to a little above C. This group has probably derived much of its material from the denudation of the great masses of rhyolitic lava to the south-west, and the lapilli which are often present may have been derived from its associated cones. At the same time, seeing that these lavas appear generally to rest upon old gneissic and granitoid rock, the slaty fragments, often very

* Which would be lithologically the least difficult, were not this grit apparently so completely “sandwiched” between the Bangor grits and breccias and the Cae-Seri breccia.

angular, would not seldom be more simply explained by supposing that sporadic volcanic action still continued, and that indurated fragments of the finer sediments formed from the denudation of the somewhat older lavas and ash were ejected together with lapilli.

I see no reason for insisting on any great interval of time between the rhyolitic lavas and the base of the Bangor beds. An unconformity there seems to be; but that in a volcanic series is of little moment; and I am of opinion that on the whole it would be better to include these quartz porphyries or quartz felsites (old rhyolitic lavas) with the Bangor group. This belongs to the disturbed episode anterior to the quiet subsidence which marks the non-volcanic sedimentary series everywhere recognized as Cambrian. From the latter we seem justified lithologically and physically in separating these more or less volcanic beds, and in including them for convenience in the Peibidian group of Dr. Hicks; but the interval in time need not have been a very enormous one. Below the rhyolites, as it seems to me, is the great gap in the record. They apparently broke forth, as the older basalts in Auvergne, upon a plateau of crystalline rocks which belong to some of the earlier, as these do to the last, chapters in the Archæan volume of the Geological History.

Notes.—As I believe that no analysis has been published of any specimen from the great masses of quartz-felsite, which occupy so considerable an area in this part of North Wales and contribute so largely to the rocks immediately overlying them, I take this opportunity of giving one, for which I have to thank my friend Mr. J. J. H. Teall, F.G.S. It was made from a very typical specimen of the common purplish variety, collected from the crag near Brithdir Farm (No. I.). For comparison, I place beside it an analysis of the “devitrified pitchstone” of the Wrekin district (No. II.), of a felstone (of Arenig age) from Aran Mowddwy (No. III.), and of a felsite of Bala age from the Lledr valley (No. IV.). The last, an analysis of a specimen of the ground-mass of the peculiar spherulitic rock described on p. 290 of vol. xxxviii. of the Quarterly Journal, was kindly undertaken for me by Mr. F. H. Hatch of University College, London, when I was engaged on my paper “On some Nodular Felsites in the Bala Group of North Wales;” but the result, owing to an accidental delay, did not reach me in time for publication.

The close correspondence between I. and II. is most remarkable. The Ordovician felsites (III. and IV.) agree fairly together, and differ from the other pair in a larger percentage of SiO_2 , a less percentage of alumina and alkalis, and in an excess of Na_2O over K_2O .

	No. I.	No. II.	No. III.	No. IV.
SO ₂	72.57	72.18	83.802	79.72
Al ₂ O ₃	13.64	14.46	7.686	9.65
Fe ₂ O ₃	2.28	1.78	.111	5.69
FeO	...	.91	.408	...
BaO	slight trace	...	...	†
CaO	1.00	0.92	.896	†
MgO	.64	trace	.109	†
K ₂ O	6.17	6.10	2.161	1.93
Na ₂ O	2.07	1.92	4.229	3.54
FeS	...	...	.191	...
Loss on ignition ...	1.10	1.47	.301	...
	99.47	99.74	100.000*	100.53

No. I. By J. J. H. Teall, Esq., F.G.S.

No. II. By J. A. Phillips, Esq., F.R.S., Quart. Journ. Geol. Soc. xxxiii. p. 457. Cf. the analyses there given of modern "perlites."

No. III. By J. Hughes, Esq., F.C.S., Quart. Journ. Geol. Soc. xxxi. p. 400.

No. IV. By F. H. Hatch, Esq.

DISCUSSION.

Prof. HUGHES remarked on the confusion among the Archæan rocks arising from their classification according to similarity of character, previous to exact determination of their relations to one another in each area. He could not agree with the author in saying that any of the beds east of Brithdir now described were identical with those of Holyhead and Amlwch. He had failed to find any break or unconformity in the British Archæan. He could not agree with the author as to the succession of grits and conglomerates indicated, as he took the strike to be in some cases at right angles to that assumed by the author; so that the author's bands, according to him, were in one part to be referred to the Cambrian conglomerate and in another part of the same band to the Bangor series. Noticing the frequency with which volcanic series, when traced along the strike, pass into ordinary sedimentary rocks, he thought that the relation of the Pebidian to beds not of volcanic origin in adjoining areas might be regarded as still an open question.

Mr. TEALL stated that his analysis had been made quite independently of that of Mr. Phillips.

Dr. HICKS remarked on the discordance of strike of the Pebidian rocks from that of the beds above and below. The granitoid, felsitic, and volcanic groups of Prof. Hughes agreed fairly well with his Dimetian, Arvonian, and Pebidian; but neither of these is fully represented here. Unquestionably the Cambrian conglomerates overlap each group with a marked unconformity, and are mainly made up of fragments derived from the groups below. This unconformity

* Including .089 phosphoric acid, .017 of sulphuric acid, and a trace of carbonic acid.

† Traces, amount not estimated.

occurs in all the areas examined. He believed that the existence of the Arvonian would eventually be fully established. He thought that the author's studies would serve to establish a fourth Archæan series in addition to his own.

Mr. TOPLEY said it was admitted by the author that the unconformity between the Cambrian and underlying beds was comparatively small and local; which was a very different conclusion from that previously announced by Dr. Hicks, who required the Cambrian conglomerate to override some thousands of feet of Pebidian beds within a distance of little more than a mile.

The AUTHOR, in reply to Professor Hughes, said that he thought all the evidence pointed to the Menai and Holyhead schists, with others inland in Anglesey, being approximately of one age. In neighbouring districts and under similar circumstances, he thought lithological correspondence gave a reasonable presumption in favour of a general correspondence in age. In the Bangor district he was fully sensible of the difficulties mentioned by Professor Hughes, especially as regards the conglomerate at Gorphyswfa and the exposures between it and the great mass running up from the shore. Still, on the south-east side of the fault, he thought the succession was clear and the improbabilities of the identity of any of the coarser fragmental beds were too great. He said, in reply to Dr. Hicks, that he did not deny that there might be a series in South Wales representing what the speaker called Arvonian; but in the Caernarvonshire districts he could not find hálleflintas, but there were true acid lavas. With reference to Mr. Topley's remarks, he stated that what he had said was, that he considered there was, under the rocks generally recognized as Cambrian, a series sufficiently distinct stratigraphically and lithologically to justify, in accordance with the usual laws, the giving of a separate name (*i. e.* Pebidian). Whether Dr. Hicks or Prof. Hughes might or might not have overestimated the amount of the break, whether they agreed or disagreed, clearly was for them and not for him to settle. Each man, in the matter of mistakes, if he made them, must bear his own burden, as the author had done by his remarks admitting a mistake of his own at Twt Hill, which had been corrected by Prof. Hughes.