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ORIGINAL ARTICLES.

I.—ON THE CLASSIFICATION OF THE BRITISH PRE-CAMBRIAN ROCKS.¹

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THE results obtained of late years, through the numerous investigations which have been carried on amongst the Pre-Cambrian rocks in Great Britain, combined with the important discoveries of many additional areas to those previously known, seem to require that some general attempt should now be made to correlate the principal groups where they have been observed; and to classify them according to the prevailing types of rocks recognized therein, and peculiarities observable.

It will be seen that the ordinary methods of investigation, used in determining the order of succession in more recent strata, are equally applicable to these; provided, we grant, that they were deposited more or less in a similar manner, and that the crystalline or semi-crystalline state in which they are now found has been subsequently induced.

This being allowed, we arrive at the probable conclusion that the sediments which hold the lowest, and hence the earliest position, are those which have undergone most change; and that this will be less marked as we ascend in the succession.

I believe that the facts obtained go to prove almost conclusively that this is the case: and, moreover, that the majority of the rocks now recognized as Pre-Cambrian were originally sedimentary strata, which have undergone, during subsequent changes, a certain amount of alteration, or metamorphism, but which still retain sufficient evidence of their origin to warrant their being classified by the same methods as those applicable to more recent deposits. That they can in fact be distinguished by special characters due to the prevalence of certain physical conditions at the time of deposition, by a well-defined order in succession, and usually by a discordance in the strike of the larger groups.

In the physical history of our globe, nothing, perhaps, becomes more evident than the well-recognized fact that its crust has been

¹ Read at the Meeting of the British Association at Sheffield, 1879.

undergoing periodical contractions along certain defined lines. That these lines have also periodically varied in their direction is well known. If we require therefore to trace out the history of these movements, we must seek for it in those strata which we know must have been elevated at the time; and whose beds must have generally assumed a strike parallel with the upward movements. Sir R. Murchison years ago pointed out the fact that the majority of the crystalline rocks in the Hebrides and North-western Highlands of Scotland had a strike from N.W. to S.E.; and hence in a direction not usual in the Cambrian and Silurian rocks.

This fact has been more or less qualified by all subsequent observations, and it is one which cannot be lost sight of in any inquiry made as to the early physical history of our islands. My own observations tend to show that the oldest known upward movements were in a direction almost due *east* and *west*, that is, that the contractions took place from north to south; subsequent elevations and depressions in a direction from N.W. to S.E.; more recent ones from N. to S., and those which immediately preceded the Cambrian period from N.E. to S.W. Each of these produced new physical conditions, with breaks in the succession along well-defined, and usually extensive, lines. Another important fact made out in these inquiries is that it may be possible sometimes to determine the age of the faults by the direction which they have taken, especially if of great extent. For example, a tolerably rigid crust under the influence of a lateral thrust acting from E. to W. would most probably fracture in a direction from N. to S. Now if we take for granted that the last sediments deposited previous to this lateral pressure being exerted were in a condition to yield readily to the contractions, as they probably would be; but that the underlying rocks would be in a hardened or metamorphosed state; it is clear that these last only would be fractured. If these movements also did take place in the direction of those which had previously acted upon these rocks, then generally the fractures would be across the beds, and in the direction of the curvatures of the overlying sediments. That is to say, the faults affecting A would be in the direction of the strike in B.

At present it is difficult to separate always those which may be called the primary faults from those produced subsequently during fresh contractions; still they may be recognized frequently, and when they are they aid greatly any attempt made to unravel the early physical changes. The oldest faults which can be traced with certainty are in a direction from N. to S. and were produced at the close of the Arvonian. They cut across the beds of the Lewisian, and Dimetian, and exposed these rocks as ridges in the Pebidian sea, and Pebidian beds are now seen resting along the sides and unconformably across the edges of these rocks. These faults therefore prove, along with other evidence, that the former rocks were crystalline ere the latter were deposited, and that they yielded by fracturing to the lateral pressure exerted from E. to W. which gave the direction of strike to the Arvonian group.

In former communications I have attempted to classify these rocks as exhibited in special districts, and I have usually found, when examining new areas, that the order which I had previously made out, as far as that evidence went, was almost invariably recognizable there also. It is this fact that has mainly tempted me to bring forward this paper to endeavour to show that a classification generally applicable to the British Islands is even now possible.

Four well-defined groups are made out, and to each of these names have already been given.

They occur in the following ascending order:—1. *Lewisian*; 2. *Dimetian*; 3. *Arvonian*; and 4. *Pebidian*.

1. The *Lewisian*, so named by Sir R. Murchison to indicate the crystalline rocks of the Hebrides and North-western Highlands of Scotland, is here retained for the oldest group at present recognized in Britain, and largely developed in the Hebrides. It is found also in parts of the Malvern chain, and the North-west of Ireland; and possibly also in Anglesey. The prevailing rocks in this group are massive gneisses, in which hornblende and a reddish felspar are the chief ingredients, and quartz, chlorite, and mica, but sparingly present. They are usually of a dusky red, grey, or dark colour. Sometimes almost a pure hornblende rock is found. The strike in these beds is usually E. and W. or some point between that and N.W. and S.E.

2. The *Dimetian*.—This group is largely developed in Wales, as at St. Davids, Carnarvon, Rhos Hirwain and Anglesey. It has been found by Dr. Callaway in Shropshire, and I have recently seen it in the Malvern chain, especially in the Worcester Beacon. I noticed it also last year in large development at Ben Fyn, Loch Maree, and near Gaerloch in Ross-shire, as well as at several other points in the North-western Highlands of Scotland. The prevailing rocks in this group are granitoid and quartzose gneisses, with pinkish, flesh-coloured, or white felspar; and with limestones, micaceous, and occasionally chloritic and hornblendic bands. Brecciated beds also occur in which bits of the older *Lewisian* gneiss are sometimes found. The strike is generally N.W. and S.E. or from this to N. and S. It evidently overlies the *Lewisian* unconformably in the areas where both have hitherto been found associated; and its highly quartzose character and lighter colour generally is in marked contrast to most of the members of that group.

3. The *Arvonian*.—At the last meeting of the British Association mentioned, for the first time, the discovery, or rather the separation of this group. It is largely developed in Pembrokeshire and Carnarvonshire. It occurs also in Anglesey and Shropshire, and I have recently found it at the base of the Harlech Group in the heart of the Harlech Mountains. I have seen masses of it also from the Orkneys, and it probably occurs both in the Western Islands, and in the Grampians of Scotland. It is the great *hällaffinta* group of the Swedish geologists, and the *petrosilex* group (Hunt) found so largely developed in North America. It is chiefly made up of

quartzo-felspathic rocks, sometimes porphyritic, frequently brecciated; and of compact quartzose rocks or hälleflintas, which on microscopical examination have the appearance of incipient gneiss. The strike is usually about N. and S.

4. The *Pebidian*.—This being the newest group in the Pre-Cambrian rocks is the least altered in character, and most nearly approaches in strike to the overlying unaltered or Cambrian rocks. It resembles that group in many of its rocks, and on that account was for a time supposed to be identical with it, only that it had undergone local alteration. Now we know that it underlies the latter unconformably, and that the apparent similarity in character is to be attributed to the fact that most of the Cambrian rocks were derived from the denudation of this group. That it was also in a high state of alteration before the Cambrian rocks were deposited upon it is evident from the fact that an abundance of pebbles and masses of it occur in the conglomerates at the base of the Cambrian. It consists for the most part of chloritic, talcose, felspathic, and micaceous schistose rocks; alternating with massive and slaty greenstone bands, dolomitic limestone, serpentine, lava-flows, porcellanites, breccias and conglomerates. It is traversed also frequently by dykes of granite, dolerite, etc. It is a group of enormous thickness, and is largely distributed over Great Britain. It occurs in many parts of Wales, in Shropshire, and in Charnwood Forest. I found it also last year in the North-west of Scotland, and I have seen specimens of it collected by Mr. James Thomson and others from Islay, and other of the Western Islands. Dr. Hunt recognized it also along the Crinan canal, and in the vicinity of Loch Foyle, in Ireland. It is probably represented in America by the Huronian Group. The prevailing strike is N.N.E. to S.S.W., or from this to N.E. and S.W.

The conglomerates at its base are largely made up of masses derived from the Arvonian; and it is undoubtedly, at most of the points examined, unconformable to that group.

These four divisions comprise at present all that we know of the Pre-Cambrian rocks in Great Britain; but it is probable that as fresh discoveries are being made others will still be found. In any case the field is a wide one, and it has at present only been barely touched, though the results have been very considerable. Many, indeed the majority of the rocks found in these four divisions were until recently supposed to be either intrusive masses, or altered sediments belonging to tolerably recent times. The success obtained of late in their separation and recognition has been largely due to microscopical examination, for the first application of which to that purpose we are mainly indebted to Mr. Sorby. In addition to this, it is becoming more and more an acknowledged fact that the metamorphism of great groups of rocks does not take place as readily as was formerly supposed, but that some special conditions, such as do not appear to have prevailed over this area since Pre-Cambrian times, were necessary to produce so great a result.