12.

[*From the* REPORT *of the* BRITISH ASSOCIATION *for the* ADVANCEMENT *of* SCIENCE *for* 1875.]

NOTES

ON THE

CLASSIFICATION OF THE SEDIMENTARY ROCKS.

BY

T. M^c^K. HUGHES, M.A., F.S.A., F.G.S.,

WOODWARDIAN PROFESSOR OF GEOLOGY, CAMBRIDGE.

Prof. Hughes, in advocating a revision of the classification of the sedimentary rocks, pointed out:—

(1) That, although the accumulation of rock-material may have been going on somewhere throughout the whole of the periods with which geologists have to do, still that deposition has been locally interrupted many times;

(2) That the whole evidence had to be considered in each case, as it was a matter of every-day observation that trifling geographical changes might produce considerable alteration not only in the character of the sediment, but also in the fauna and flora of a given area; and small local irregularities, due for instance to volcanic action, might produce phenomena which alone would be taken for an unconformity, implying a long interruption of deposit;

(3) That denudation proves a lapse of time somewhat commensurate with the deposition of a similar thickness of material to that denuded.

Bearing these principles in mind, he observed that the great divisions should be drawn where it can be shown there was the greatest and longest interruption in the continuity of conditions, the minor subdivisions being founded upon more rapidly varying circumstances, which often produce even greater difference in lithological character and fossil contents.

He pointed out that our present classification was very inconsistent—some of the breaks within the Primary, for example, being far more important than that between the Primary and Secondary rocks themselves.

He proposed the following classification, read in ascending order:—

1*st Epoch.*	*Laurentian.*	*Pre-Cambrian.*
2*nd* „	*Gap.*	
3*rd* „	*Labrador Series.*	
4*th* „	*Gap.*	
5*th* „	*Huronian?*	

The Huronian he felt to be not quite well defined, but thought it probable that

a group would be made out between the Labrador series, or Upper Laurentian, and the Cambrian. He considered that the attempt to identify the subdivisions of the pre-Cambrian rocks in distant countries (Britain and America for instance) was premature. Calling attention to the two unconformable groups which Dr. Hicks had made out at St. David's, he felt satisfied that the Cambrian was unconformable to the upper as well as to the lower, and stated that he had himself found fragments of the hornstones, *i. e.* the Upper pre-Cambrian group, in the conglomerates at the base of the Cambrian. The oldest rocks of N.W. Scotland, of the Malvern Hills, and of Scandinavia, he thought could at present only be safely called pre-Cambrian.

6th Epoch. Gap between Huronian and Cambrian.—Since we have in Britain certainly two, and in America probably three series of deposits before the Cambrian, and the Cambrian may rest on any one of them, it is impossible to estimate the duration of the period between the Cambrian and the newest of the pre-Cambrian rocks.

7th Epoch. Cambrian.—He referred especially to the labours of Dr. Hicks, and thought that there were no hard and fast lines of demarcation between different subdivisions of the Lower and Middle Cambrian, but only zones of life, and that the boundary-lines between the portions of the series in which these zones of life occurred were continually being shifted. Sometimes, where a change in the sediment happened to come between two zones, this was seized upon as marking a convenient place to draw a line. Such a boundary was that offered by the Garth Grit, which comes between the zone of *Angelina Sedgwickii* and that of *Æglina binodosa*. No life zone older than this last appears to have been yet made out in the Lake-district. This grit is not a conglomerate formed of fragments of the underlying rock, but is made up almost entirely of quartz-pebbles, small and well worn, as if derived from a distance. A precisely similar grit occurs associated with somewhat similar slate low down in the green slates and porphyry in Chapel-le-Dale on the S.E. border of the Lake-district, probably not very far above the horizon of the Garth Grit. It is like the grit which occurs frequently in South Wales in the Caradoc beds, in the Denbigh Grits in North Wales, and in the Lake-district in the Coniston Grits, and in all these cases is known to be far above the base in a conformable series.

A great part of the series above this horizon is, in the Lake-district and in North Wales, made up of volcanic ejectamenta. In North Wales the ash and lava seem to have been deposited in the sea and modified by its action; while in the intervals between the periods of volcanic activity various forms of marine life lived on the muddy bottom, which enable us to correlate the beds with the Bala series. In the Lake-district the sea seems to have been filled up by the immense quantity of material thrown out, and much of the accumulation is supposed to have been subaerial. In both districts volcanic activity seems to have ceased, while the fauna of the Bala Limestone still inhabited the area; and subsidence went on while the Bala and Hirnant Limestones, with a great mass of interbedded and overlying flags, were deposited in North Wales; and in the Lake-district the corresponding deposits, viz. the Coniston Limestone, Fairy-Gill Shales and Ash-Gill Flags (=Lower Coniston Flags), were formed. In South Wales and the western borders of England only a few ash-like beds suggest the not distant line of volcanic outbursts. Scotland, Scandinavia, Bohemia, and America yield a series which, if not in detail, can in a general way be correlated with these. The fact that the Lake-district and North Wales were during this period the seat of old volcanoes, will partly explain the difficulty that was experienced by Prof. Sedgwick and Sir Roderick Murchison in identifying the corresponding beds in the two areas independently examined by them; and the sudden ending of the volcanic deposits may probably account for the local apparent irregularity of the Coniston or Bala Limestone on the underlying series, which induced Professor Sedgwick to make that limestone the base of his upper subdivision, and which has recently been urged as proofs of an unconformity by Mr. Aveline. Except in connexion with the volcanic deposits, no break has been proved from the conglomerates which form the base of the Harlech group to the top of the Bala series.

8th Epoch. The Gap between the Cambrian and Silurian.—This he thought not strongly marked, and certainly not to be drawn between the Upper and Lower

Llandovery. He criticised the palæontological and other evidence upon which this division had been made, and protested against the introduction of the name Llandovery Rocks instead of May-Hill Sandstone, under which it was first described by Prof. Sedgwick. In the Lake-district and in North Wales in every open section there was an apparent conformity, though the overlap of the Graptolitic mudstone, from the Coniston Limestone of Windermere to the Ash-Gill Flags of Coniston, seemed to suggest an unconformity. The May-Hill Sandstone, thinning out to the north and creeping over the edges of the Cambrian rocks and along the ancient mountain-range of the Malvern and Longmynd, rests on the oldest parts of the Cambrian and even on the pre-Cambrian. Still this cannot be said to represent the previous denudation of the whole thickness of the Cambrian rocks, as they themselves thin out against the old Malvern ridge; so that this epoch would appear to have been characterized in the typical regions by the upheaval of some mountain-chains and irregular movements in large adjoining areas.

9th Epoch. Silurian.—This series he thought commenced with the base of the May-Hill Sandstone (*i. e.* at the bottom of the Lower Llandovery, with some corrections of boundary). There was a very considerable change in the forms of life, and this was conspicuous even where the stratigraphical discordance was not well marked. There was little difference of opinion as to the grouping of beds, except at the commencement and close of the period. Conglomerates mark the base at Austwick and Sedbergh, on the western borders of the Lake country, accompanied by a change in the character and colour of the sediment and of the organic remains. The boundary can be traced through the Lake-district proper, and in North Wales by the same change in the fossils and the sediment, but there is no conglomerate. In South Wales a conglomerate frequently marks the base; but the group of fossils that comes on first is very different, and seems to suggest an earlier submergence of the southern area.

Passing over the Wenlock and Ludlow, the next difficulty is in drawing the upper boundary. This he would take at the top of the red shales and marls of the river Sawdde and the country east of Horeb Chapel in South Wales; for there is no evidence of a break there or anywhere else between the tilestones and the red shales; and where fossils have been found, as at Ledbury, in the red shales they are common Ludlow forms.

The author pointed out, by reference to original and published sections by Prof. Sedgwick, that the views he now advocated as to the classification of the Cambrian rocks and the position of the boundary-line between them and the Silurian were exactly those of Prof. Sedgwick. He further showed, by comparison of the map and sections of Murchison with those of the Survey and later authors, that Murchison had not, in 1839, correctly placed any one of the beds about which he later came into collision with Sedgwick; that the Caradoc of Murchison's sections, supposed to rest on the Llandeilo Flags south of Llandeilo, was May-Hill Sandstone or Wenlock; that the Cambrian rocks, supposed by Murchison to crop out from below the Llandeilo Flags, were Caradoc and newer beds overlying it; that the supposed base of the Llandeilo Flags was in fact the top. He further stated that when these errors were corrected there was no acknowledgment of the approach made in the new editions to the original classification of Sedgwick; that the latest change had carried the base of the Silurian below the unconformities in the Cambrian rocks given in vol. iii. of the 'Memoirs of the Geological Survey,' and had left it where he thought no one would now venture to suggest there was any palæontological or stratigraphical break. As this must be changed, and the unconformities above mentioned would, he thought, be certainly abolished before long, he asked whether for justice and consistency we should not, in adopting Prof. Sedgwick's classification, adopt his nomenclature also.

10th Epoch. The Gap between the Silurian and Carboniferous.—This he considered one of the two most strongly marked gaps (except, possibly, some pre-Cambrian intervals) in all the geologic series. In the north of England the Cambrian and Silurian rocks were folded and denuded down to the Skiddaw Slates: strata to the thickness of at least five or six miles were removed. In the north-west of Wales a similar denudation seems to have been going on; but as we turn to the east we find, along the Vale of Clwyd for instance, that there

was not such great contortion and denudation previous to the deposition of the basement-bed of the Carboniferous rocks. The patchy sedimentary base, consisting of sands and conglomerate, rests on the Denbigh grits and flags. Skipping the region of mid Wales, we find in South Wales still less pre-Carboniferous crumpling and denudation. As pointed out above, higher beds belonging to the Silurian series are left than any seen further north; and the sedimentary base of the Carboniferous is thicker. Still further south (in Devonshire &c.), though the actual base is nowhere seen, we have the sedimentary series more strongly developed; and the early type of Devonian fossils agrees with the idea that the Devonian area went down first at the commencement of the Carboniferous epoch.

11*th Epoch. Carboniferous.*—In accordance with the above view of the pre-Carboniferous geographical changes, the author, while disagreeing with Prof. Jukes in his interpretation of the stratigraphical structure of Devonshire, still goes with him in bracketing the Devonian with the Carboniferous, and would refer to the same age most of the Old Red of Scotland, while a great portion of the Old Red of South Wales he would group with the Silurian. Running over the principal subdivisions of the Carboniferous, and noticing the occurrence of coal-seams at lower and lower horizons as we proceed from S. to N., the author next drew attention to the large masses of rock of Carboniferous age which had been so deeply stained from the overlying New Red that they had been grouped with that formation; and pointed out that as we approach the newest known beds of Carboniferous age, we find indications of the commencement of earth movements in the local irregularities in the sequence of the uppermost Coal-measures.

12*th Epoch. The Interval between the Carboniferous and New Red.*—This he considered the second most important gap in the geologic series. The geographical changes which occurred in it were the hardening and upheaval of the whole of the Carboniferous (and how much besides we have not evidence to show), the carving-out of these rocks into hill and valley, and the development of a flora and fauna differing considerably from those preserved in the Carboniferous rocks. As the base of the New Red rests on the edges of rocks from one to four miles in thickness, this epoch must have been of very long duration.

13*th Epoch. New Red and Jurassic.*—This epoch, like the Carboniferous, commenced with the variable deposits accumulated along the shores and in the lakes and valleys of an irregular continent unequally submerged. They consist of conglomerates, sandstones, and mudstones, and, like those at the base of the Carboniferous, generally of a bright red colour. The red stain penetrates deep into the underlying rocks, the surface of which often shows evidence of subaerial weathering. What wonder that, as headlands disappeared, as barriers went down, as depressions got silted up, there should be irregularities of all kinds observable between successive deposits—such, for instance, as that at the base of the Upper Magnesian Limestone in places, or that between the Lower and Upper New Red, or that between the Bunter and Keuper. (He dropped the word Permian, as it was only a new name given by Murchison to what had been previously correctly described by Sedgwick as Lower New Red.)

These rocks passed up through the Rhætic and Lias into the Oolitic series, at the close of which, as in every other case, we have a hint of the approaching changes. Probably we shall some day have sufficient data to speculate on the limit to which it is possible that continuous deposition can go on uninterruptedly in the same area. However that may be, the further on we get in geologic history the more clear does the evidence become that, as great waves of depression pass across an area, sometimes the accumulation of sediment keeps pace with it, and leaves deposits which show that the hollows had been filled and lagoons and estuaries had taken their place by the time the trough of depression had passed and the wave of upheaval had succeeded. Towards the close of the Jurassic epoch, at any rate, we have the Purbeck freshwater beds, and later the Weald estuary, where we know there had been hundreds, and probably thousands of feet of continuous marine deposits.

The author then considered briefly the gaps which occurred at the base of the Neocomian and of the Cretaceous, and the intervals of which we have evidence at the base of the Eocene and of the Miocene, but reserved the fuller investigation of these points for a future occasion.