

In several future chapters we shall endeavour to trace the successive manifestations of the volcanic forces in the same area, and to show their relations to the tremendous exhibitions of force resulting in those grand movements by which the Alpine rocks have acquired their present positions and relations.

P.S.—I am indebted to my friend, Prof. vom Rath of Bonn, for calling my attention to an error into which I have fallen in the last chapter of this series. On page 54, I have classed the gaseous exhalations of the Büdos Hegy in Transylvania with those of the Solfatara, as having an elevated temperature. This is not the case, however, the gas evolved at the former locality having the same temperature as the surrounding atmosphere.

(To be continued.)

IV.—SOME CONSIDERATIONS ON THE PROBABLE CONDITIONS UNDER WHICH THE PALÆOZOIC ROCKS WERE DEPOSITED OVER THE NORTHERN HEMISPHERE.

By HENRY HICKS, F.G.S.

(Continued from page 160.)

Upper Silurian.—At the close of the Lower Silurian, as already stated, changes of considerable importance took place in some of the areas which had undergone depression. The sea-bottom was now raised in parts of Western Europe, and in North America, and islands of some extent formed. In Europe the most important were those in North Wales, Shropshire, Cumberland, the South of Scotland, and in Nassau. It is probable also that one or more extended along Southern Europe, from Portugal into Spain, etc., but the evidence concerning this is as yet imperfect. In America, according to Logan, Dana, etc., the principal parts raised at this time were the Green Mountain regions, and the ridge extending from Lake Erie over Cincinnati into Tennessee. These American ridges appear to have been raised to a great height, and to have remained afterwards in part dry land, even to the close of the Palæozoic. The islands in Europe were raised only to a small height above water-level, and were probably all again submerged by the close of the Upper Silurian. The uplifting did not take place in Britain until after the close of the Bala period, or after the Upper Bala Limestone had been formed over the British area. The changes may be said, therefore, to have taken place when the Lower Llandovery rocks were being deposited over the parts still submerged. The uplifting in Europe occurred chiefly in regions where volcanic action had previously taken place, and the changes seem to have been produced on the whole rapidly. For instance, in Wales the upheaval, and a subsequent depression of most of the upheaved parts, must have taken place during the time that the Lower Llandovery rocks were being deposited in the surrounding sea, for in many places the Upper Llandovery rocks may be now seen resting on the upturned edges of the Lower Silurian beds. Again, as the Lower Llandovery rocks appear to have been made up for the most part from the denudation of these islands, where an abundance

of loose material was ready at hand, it is evident that the change must have been on the whole rapid, and that a depression of the crust even in those parts again soon followed that of elevation. The elevation, as already stated, occurred only over a very small proportion of the Northern Hemisphere, compared with that in which depression was going on. The subsidence also in the larger areas continued to go on uninterruptedly at this point, and we find therefore that the beds which can be considered in any way the equivalents of the Lower Llandovery rocks of Wales in these undisturbed areas are very insignificant, and usually have no well-defined boundary.¹ I know that the generally received opinion is that these changes took place very gradually; but I think the above evidence tends strongly to show that elevation as a rule was rapid, compared with that of depression; and I further believe that it was so in all the changes which took place up to the close of the Palæozoic. The sediments which make up the earlier Upper Silurian rocks in the neighbourhood of the uplifted parts are such as would result from the denudation of these, and hence all conditions may be seen from those of beach pebbles to the very fine muddy sediment deposited at a distance from land. The Upper and Lower Llandovery rocks (including the May Hill Sandstones and Denbighshire Grits) show this clearly, and any variation in thickness or in composition is due to this cause. In the parts which remained submerged, as Pembrokeshire, Carmarthenshire, and probably Cardiganshire in South Wales, the sediments form a conformable series from the Lower to the Upper Silurian, whilst in the immediately disturbed areas an unconformity might be seen at any point up to the close of the Upper Silurian.

The higher groups in the Upper Silurian are made up of sediments, formed during periods in which a gradual depression of the sea-bottom was generally taking place. In Britain they are composed of an admixture of argillaceous material and of limestone. In the immediate regions of the parts at this time above water, but little limestone occurs, the rocks being made up almost entirely from the denudation of these islands. In France and Spain these groups are scarcely represented, but in Bohemia, Norway, Sweden, Russia, and in parts of Asia, they are represented chiefly by limestones. In North America by limestones, in the western and undisturbed regions, and partly by schists and sandstones along the eastern areas, or in the parts which had been disturbed at the close of the Lower Silurian (see Table, p. 156). The Upper Silurian period, therefore, was one of continued and gradual subsidence in apparently most of the European, and of the North American, and probably also of the Asiatic areas. The thickness of the series varied of course greatly in different regions, and the composition also, as we have shown, in proportion to the local changes which took place. The lines of

¹ The following facts concerning the fossils, kindly communicated to me by Mr. Etheridge, F.R.S., strongly support this view of rapid deposition for the Llandovery rocks. Of the 143 species which occur in the Lower Llandovery in Britain, 17 only can be said to be restricted to that formation; and of the 236 species which have been found in the Upper Llandovery, 47 only are peculiar to that series.

depression recognized to have been marked in Cambrian times were not wholly obliterated in the Upper Silurian. The lines of migration of the faunas indicated in my former paper remained also apparently still to be the prevailing ones. The Cambrian and Silurian epochs seem to have been parts of the greater Palæozoic time, perfectly natural in their order of succession, and showing no signs of want in continuity when not interfered with by local changes. In Britain, as we have seen, the succession was checked in limited areas; but even here, generally, it cannot be said that any intervals of time are unrepresented by stratified formations, as supposed by some geologists. I would rather say that not only are all the lesser epochs represented in parts of this area (South Wales, etc.), the first or nearly so of all the European areas to become submerged; but that in addition, so far as sediments are concerned, some of the epochs here have an exaggerated importance from the presence of an excess of material derived from volcanos, and from the islands formed by the uplifted portions of the sea-bottom.

Devonian and Carboniferous.—The physical conditions of these later epochs of the Palæozoic have been so frequently and so fully treated of by such eminent authorities as De la Beche, Sedgwick, Murchison, Ramsay, Prestwich, Etheridge, Geikie, etc., in Europe, and by Logan, Dawson, Dana, etc., in North America, that it will be only necessary for me to refer very briefly to them. The condition in the early part of the Devonian was like that at the close of the Upper Silurian, and the depression continued to go on regularly and uninterruptedly at this time in most parts of the Northern Hemisphere. It appears to have gone on persistently also to the close of the epoch in some areas, but in others about the middle, and from that to its close great changes took place, and the sea-bottom was there again raised above the sea-level. Volcanic outbursts also took place at this period, and a considerable amount of volcanic material was spread out, forming, in some places, islands in the sea, as between the Grampians and the Tay in Scotland, etc. The disturbances during this epoch, like those at the close of the Lower Silurian, occurred chiefly in the western areas in Europe, and along the eastern borders of North America. The differences which are now observable in the sediments belonging to this period in various parts were produced by, and hence dependent upon, the local changes that had taken place. In the undisturbed submerged regions limestones alone were formed, as in the previous epoch. Near the uplifted portions, sandstones and the usual materials to be derived from denudation, were deposited.

These changes gave an entirely new aspect to the Northern Hemisphere, and before the close of the epoch large areas of dry land and numerous lakes and inland seas extended in many directions. During the Carboniferous epoch, most of these areas were again depressed, and marine sediments very generally deposited. Where the sea bottom remained undisturbed, as in South Wales, Devonshire, etc., the sediments belonging to these two epochs are perfectly conformable to one another; but in the disturbed areas

an unconformity is of course shown. Because of the unevenness of the sea-bottom at the commencement of the Carboniferous epoch, it is difficult to estimate the amount of the depression which now took place; but since the sediments belonging to this period in some cases are as much as from 15,000 to 18,000 feet in thickness, it is evident that it must have been very considerable in extent. This period of gradual subsidence was followed again by great movements in the earth's crust, accompanied in many cases by violent volcanic action. Enormous areas were now upheaved to a great height, and mountainous ranges formed. The depression which had been gradually taking place over so large an expanse of the Northern Hemisphere seemed also at last to have reached its limit, and the land surface was now restored, partly in its proportion, though not in its general appearance, to the state it was in at the close of the Laurentian, or before the Cambrian rocks were deposited. Three periods of great disturbance occurred in Palæozoic time, and they were progressively more violent in their effects. Each also followed epochs of quiet and gradual depression, and they were most marked in the areas first submerged, where most sediment had accumulated, and hence where the pre-Cambrian crust had apparently become thinnest. The depression in some places for the whole of the Palæozoic could not have been less altogether than 50,000 feet, and conformable sediments to that extent are now found in some of the areas first submerged, and which remained undisturbed. In the south-west of Wales, where they attain this thickness, the same folds affect the whole series, from the Cambrian to the Carboniferous, and it is evident that in this region these deposits are all perfectly conformable to one another, though so near to the disturbed area of North Wales.

Along the eastern borders of North America (Appalachian region, etc.) the average thickness of conformable sediments, according to Hall, Dana, etc., is not less than from 40,000 to 45,000 feet; therefore the depression there must also have been nearly as great as that which took place in the western borders of Europe.

(To be concluded in our next Number.)

V.—CONCRETIONS.

By W. H. PENNING, F.G.S.,

Of H.M. Geological Survey of England.

THERE is a fine exposure of the "Lower Greensand" in a railway cutting by Sandy Station on the G.N. and L. & N.W. Railways, presenting a nearly vertical section 50 or 60 feet in height. It consists almost entirely of clean sand, in parts false-bedded, and more or less coloured throughout by the presence of oxide of iron. The colour thus imparted to the sand varies from almost pure white, at the lower part, through shades of grey and yellow, to a deep rusty brown. There are here and there layers of hard ferruginous concretions in tabular, spherical, and many other forms, presenting a feature hitherto (so far as the writer is aware)