General Remarks on the Coal Formation of the Great Valley of the Scottish Lowlands. By Lord GREENOCK, C. B., LL. D., V. P. R. S. Ed., F. G. S.

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THERE is perhaps no geological problem of greater interest than that by which the conditions of the globe, in respect to the distribution of land and water, at the epoch of the coal formation, might be determined, if the necessary data for its solution could be obtained. We possess sufficient evidence to shew that, since that period, most of the continents and islands of the present day have been elevated above the waters, under which they were originally formed ; but such proofs are altogether wanting when we endeavour to restore, in imagination, the probable extent of the older formations that might then have existed as dry land, but which now lie buried in the depths of the ocean, or have since been covered by an accumulation of more recent deposits.

If we consider the immense quantity of detrital matter, that must have been required to form beds of such prodigious extent and thickness, as many of those which are met with in the coal-fields of different parts of the world ; we shall naturally be led to the conclusion that, in the immediate neighbourhood of these deposits, much more extensive tracts of land must have existed, in connection with each other, than could possibly have been afforded by the older portions of the present countries. For whatever might have been the conditions of the globe, in this respect, at that epoch, we have convincing proofs in the organic remains of plants, which abound in all the members of the carboniferous series, as well as in the acknowledged vegetable origin of the coal

itself, of the pre-existence of a sufficient extent of dry land, clothed with a luxuriant tropical vegetation, to have supplied this detritus and these remains, and sufficiently elevated to have given rise to the rivers and torrents, by the action of which this transported matter must have been carried down into the lakes or estuaries, in which, to all appearance, such deposits were formed. Whether this land constituted groups of islands, according to the opinion of many geologists, or continents of greater or less extent, which, by subsequent revolutions, have been either wholly or partially submerged by the existing sea, is not our present object to inquire; but, from the size and position of the fossil trees enveloped in many of the beds of this formation, and other phenomena connected with them, there appear to be strong grounds for inferring that the volume of water discharged by these rivers, and the magnitude of their estuaries, must have been much more considerable than would probably have been the case if they had been situated in small islands; and the occurrence of terrestrial plants, with the remains of fishes, and of mollusca, that had either been the inhabitants of fresh-water or of shallow seas, in the lowest beds of the series, which have afterwards been covered by other deposits more decidedly of a marine character, seems to shew, that, although the former might have been originally deposited in lakes, or on flat shores near the mouths of rivers, frequent alternations in the relative level of the sea and land may probably have taken place since, by which a corresponding succession of deposits, varying accordingly in the character of their organic remains, have been produced.

The intermixture, however, of organic remains of a fluvatile character, with those of marine fishes and shells, is very general throughout the coal-measures, and it is still doubtful whether any well-authenticated proof exists of any beds having yet been discovered in the carboniferous series, which, from their organic contents, could be pronounced to have had exclusively a fresh-water origin, unless an exception should be found in the lime-

stone noticed by Mr MURCHISON at Pontesbury, and other places in the Shropshire coal district; for the opinion expressed by M. AGASSIZ, relative to the ichthyolites which have been found in the Scottish coal-fields, has shewn that neither the Burdiehouse limestone, nor any of the other beds of the carboniferous group in this country, with which we are at present acquainted, have any claim to be so considered; nevertheless, there are peculiarities in the character of the limestone at Burdiehouse, both in regard to its organic contents, and to its position in the series, which render it an object of the highest geological interest: and the discovery by Dr HIBBERT, of a new species of sauroid fish, the *Megalichthys*, in that limestone, is one of the most important that has been made in the present times.

In Scotland, the greater part of the secondary formations, including the coal-measures, have been deposited in that extensive district which now forms the great valley of the Scottish Lowlands, and separates the primary country, of which the northernmost extremity of Great Britain is chiefly composed, from the transition chain of the southern border (at that time probably partly submarine), which may be geologically considered as the South Highlands.

According to WILLIAMS*, a line drawn from the mouth of the Tay, passing through Stirling to the northern extremity of the Isle of Arran, and another nearly parallel to it from St Abb's Head on the east coast, to Girvan on the west, will include between them the whole of the coal-fields of Scotland, with the exception of the insulated coal basins on the Nith and the Esk in Dumfriesshire, and the seams of coal that have been worked in Roxburghshire and on the coast of Berwickshire. The coal beds of Brora, and those that have been met with in some of the Hebrides, have generally been referred to formations of a more recent period.

* History of the Mineral Kingdom, vol. ii. p. 302.

These lines are merely noticed here, in order to convey a general idea of the space occupied by the coal districts of the Scottish Lowlands; but they can by no means be considered as defining their precise limits with any degree of accuracy. On the south side of the great valley, these coal-measures follow the sinuosities of the transition hills by which they are bounded in that direction. Towards the north, although secondary strata referable to the lowest members of the carboniferous series are met with, skirting the base of the North Highlands, no workable coal (of the same formation) appears to have been found beyond the Tay, or to the northward of the boundary Mr WILLIAMS has indicated.

Although coal may not occur in equal abundance in every part of the district included within the limits specified, the causes by which it was produced having probably been influenced during their operation in a greater or less degree by local circumstances, in consequence of which a more copious deposition of the vegetable and bituminous matter from which this valuable combustible was derived, as well as a greater or less difference in the organic contents, or mineral character, of the associated strata may have taken place in some situations than in others; yet, when we consider that, with a few exceptions, only occasioned by the partial intrusion of rocks of another description, the whole extent of this space is occupied by an alternation of limestones, sandstones, slate clay, bituminous shale, coal, and ironstone, containing all the characteristic indications of their being members of the same formation, we have fair grounds for supposing, that although now separated into different fields or basins, the whole of the coal-measures throughout this extensive district were in all probability originally connected: the strata appearing to have been deposited more or less in a horizontal position, according to the force of the currents by which their materials had been transported, and to the nature of the surface upon which they were thrown down at the bottom of the sea, that must then have covered at least the whole of that portion of

the Scottish Lowlands, forming either a strait or channel between two islands, or perhaps a vast estuary into which the rivers of the neighbouring primeval countries discharged their waters. The ripple marks, which are so remarkably displayed on the surface of the different beds of this series, even of those which are now the most highly inclined, likewise afford very strong evidence in favour of this supposition.

If we examine the nature of those portions of the district referred to, which form the exceptions to that regularity and continuity of the beds of the carboniferous series, we have supposed to have prevailed at the period of their deposition, we shall at once see that the rocks of which they are composed; although equally formed beneath the sea, could not like them have been mechanically produced by the transporting action of water, their crystalline character, and the various phenomena exhibited in their relations with the fossiliferous strata, affording sufficient proof of their origin having been due to a different agency, as well as that the ranges or groups of hills of the same description, which are now seen to interrupt or cut off the coal-measures separating them, into the fields or basins in which they are found at the present day, have for the most part been elevated at periods subsequent to the deposition and consolidation of that series.

It is now generally admitted, that these trappean hills and rocks are of igneous origin, the eruptions of porphyry, greenstone, or basalt by which they were produced having taken place from submarine volcanoes, or through cracks or fissures in the previously existing strata which at that period formed the bottom of the sea, over the surface of which the igneous matter appears to have been poured out in sheets of greater or less extent, either continuously, that is to say, one stratum overflowing another in constant succession, so as to form the immense overlying masses which everywhere present themselves to view in the coal mea-

sures, enveloping and carrying up in its passage large fragments of the broken strata, and exhibiting all those signs of violence and intrusion which such rocks so frequently display; or they may sometimes have been followed by sufficient intervals of repose, to have admitted of new deposits of sandstones, shales, or limestones, above the produce of each successive eruption, and in this way the interstratification of the trap with these beds, may be accounted for in those cases in which few, or no marks of disturbance are visible.

To the effects of Plutonic action during the carboniferous epoch, which may have been in activity for ages under the pressure of the superincumbent ocean, may be referred, besides the dislocations and undulations by which the strata are broken and distorted, those gradual risings and depressions of the land which it seems necessary to admit, in order to explain the alternations we so frequently meet with in the coal-measures, of beds teeming with the remains of marine animals, with others in which they are totally wanting, or that contain only those of terrestrial plants. In fact, they appear to have been the means of gradually preparing the countries occupied by these deposits, for the purposes which, in after times, they were destined to fulfil, when, by a renewal of the same agency, both descriptions of rocks were simultaneously lifted up above the waters in their consolidated state, to the positions they relatively occupy at the present day.

Nor is the infinite wisdom that has presided over the formation of our planet in this, as well as in every period, apparent only in the changes that have been thus produced in the configuration of its surface; for when we consider the various ways in which these subterranean convulsions may have influenced the chemical changes and combinations of the vegetable, animal, and gaseous matters, through which the coal itself has been brought into its present combustible form, they evidently appear to have been the chief agents employed by the wise design of a beneficent Providence, in the modification of this important deposit, by

which it was prospectively adapted to the future necessities of the human race, which was not to be called into existence until after the lapse of a long succession of geological epochs.

The Pentland, Campsie, and Ochill Hills, as well as many others that occur within the limits specified, afford numerous and striking examples of the effects produced by their intrusion among the carboniferous strata, which, indeed, are no where better seen than in the Plutonic group that surrounds Edinburgh.

The Pentland range, which lies in a direction from south-west to north-east, is prolonged to the shores of the Frith of Forth by the trap-hills of Edinburgh, separating the coal deposits of East and Mid-Lothian from those which are situated to the westward of that chain, and form the great coal district in the basin of the Clyde. These hills bear strong internal evidence of their having been elevated at periods subsequent to the consolidation of the carboniferous series. In the midst of the Pentlands, a mass of sandstone has been thrown up, which forms a hill of considerable elevation ; and, although grauwacke-slate, and portions of a conglomerate of the same age, are seen at Habbie's-How, enveloped in the porphyry, it is highly probable that, if many of the rocks of this range, which have hitherto been referred to the transition period, were subjected to chemical analysis, they would be found to consist of the sandstones or the slate-clay of the coal-formation, altered to their present appearance by the effect of the igneous rocks with which they are in contact.

The occurrence of glance-coal, both in veins and disseminated in the porphyry and trap tuffa of the Calton Hill, and, in a similar manner, in most of the other hills of this group, tends also very strongly to confirm this opinion ; for it has most probably been caused by the igneous matter having burst through the coal strata in a fluid state, carrying up fragments of the coal with it, which, being by this process deprived of their bituminous qualities, have been converted into anthracite.

The Campsie Hills particularly, in the neighbourhood of Kilsyth, exhibit several magnificent sections illustrative of the period and manner of their elevation, when viewed in the relations they are there seen to bear to the carboniferous series. In the Bathgate Hills, and in Stirlingshire, coal and limestone are worked beneath columnar trap; and, indeed, the whole country occupied by the Scottish coal-measures displays more or less the effects produced by the influence of such igneous hills, or of the dykes connected with them, some of the former rising into mountain masses, others forming detached hills, either lofty and rugged, or scarcely elevated above the level of the surrounding country; while many of the latter do not penetrate to the surface, but remain at greater or less depths beneath it, producing much disturbance in the strata below, as well as many of the dislocations and elevations that are observed above ground, although the cause itself may not be perceptible.

When viewed collectively, a certain degree of parallelism may be observed in the principal chains formed by the hills of this nature, their general bearing being from the westward of south to the eastward of north, which corresponds with the general strike of the fossiliferous rocks; and they sometimes appear to assume a circular arrangement, encompassing valleys or basins of greater or less extent. This, however, cannot be said to be the case with respect to the smaller groups or insulated masses, many of which seem to have been protruded through the strata at different times, and under varying circumstances, without any apparent order or regularity; and the dykes are found to proceed in every direction from the principal masses, in some cases appearing to radiate from them as centres.

Besides the interruption occasioned to the coal measures by the elevation of the hills, by which the coal-fields are now separated from each other, their connection has in many instances been more or less cut off by rivers, estuaries, or portions of the sea, the beds of which have been formed in these deposits. This

is particularly exemplified by the Clyde, the Frith of Forth, and very probably by that part of the Irish Channel which is situated within the prolongation of the lines before adverted to, as they flow through or cover strata of the coal formation, which though now removed by, or concealed beneath their waters, we have every reason to presume had once been continuous with those that are still visible on their opposite shores.

The connection between the Lothian coal-fields and that of Fifeshire, is very apparent, both in the general direction of the strata as shewn by their outcrop on the opposite shores of the Frith of Forth, and in the number and thickness of the beds of coal in each, which exactly correspond. Coal, too, is worked to some extent under the bed of the Frith at the Wemyss colliery in Fifeshire; but, in consequence of the frequent dislocations and other changes that may be attributed to the influence of igneous rocks, it would be difficult to establish the complete identity of each particular stratum on both sides of the water.

The carboniferous strata seen in the Island of Arran, and at Campbellton in Kintyre, appear to be only portions of the bed of the Irish channel, that have either been brought up to their present positions by the elevation of the plutonic rocks with which they are associated, or left in those situations when the disruption took place, by which that channel was formed; for although the coal district does not immediately shew itself on the Irish coast except at Ballycastle, being cut off by the trap of Antrim, there are still sufficient indications of its former existence along that shore, to prove the geological connection in this, as well as in most other respects between the west of Scotland and the north-east of Ireland.

The Scottish coal-measures having hitherto been very imperfectly described, their exact position in the series, as compared with that of the coal formation of England, has never been precisely determined; and although more than forty years have elapsed since the remarkable organic remains which have lately

excited so much interest were first noticed in the coal-fields of Scotland, the important conclusions that might have been derived from this valuable addition to the palæontology of that period appear to have been entirely overlooked.

It may, however, be worthy of notice in this place, that although traces of some of the more recent secondary formations, such as the lias and oolite, and even chalk flints, have been observed in the northern parts of the island where primary rocks chiefly prevail; none whatever of a later date than the coal-measures (if we except the alluvial deposits) have been met with in the Great Valley of the Scottish Lowlands. For the red sandstones of that district do not appear in any instance to have been identified with the new red sandstone of England, but they have, apparently on good grounds, been referred by the best geological authorities to the lower part of the carboniferous series.

Professor SEDGWICK * and Mr CONYBEARE † have remarked that some of the inferior beds of the English coal-measures, such as the millstone grit and limestone shale, which are but of little importance in the southern coal-fields, spread out as they proceed northwards, presenting subordinate beds of coal; and as these strata approach the transition chain of the Scottish border, the lower beds of the carboniferous limestone, in like manner, become subdivided, and alternate with coal, sandstone, and shale, the calcareous beds decreasing, and the coal-beds increasing, until they assume the character of a regular coal formation, to which that of Scotland bears so much analogy, as to render it highly probable that the same law has extended beyond these mountains, and that the Scottish coal-measures occupying the great valley of the Lowlands, are equally referable to the lower beds of the carboniferous limestone group.

* SEDGWICK's Address to the Geological Society, 1831.

† CONYBEARE's Report on Geology, Transactions of the British Association, vol. i.

Mr DE LA BECHE, in a recent work on theoretical geology,* from a consideration of the facts connected with these coal-measures, is led to the conclusion, that, at the period when the carboniferous limestone of the south of England was produced in the sea, there was probably dry land in the part of the European area not far to the northward of the present Tweed, and that a gradual rise of the land was effected, by which means terrestrial vegetation travelled farther to the south, so that its remains became abundantly entombed in that direction, producing the coal now found in Southern England and Wales, as also in Belgium and Northern France, the continuity of the whole being superficially concealed by the more recent secondary and tertiary deposits of those countries.

But, as Mr DE LA BECHE so justly and eloquently adds,† “ To trace even the probable positions of dry land over the European area at the carboniferous epoch, would be most difficult, particularly when we recollect that what we term a geological epoch, may include a long series of ages, and that thus land may rise and fall, be degraded and replaced, sometimes by the same, sometimes by greater, intensities of various forces than those the effects of which we daily witness, and yet the whole be included in a geological epoch, or rather one during which a particular group of rocks has been formed.”

* Geological Researches, p. 318.

† Ibid. p. 322.