2. *On the Association of the Lower Members of the OLD RED SANDSTONE and the METAMORPHIC ROCKS on the SOUTHERN MARGIN of the GRAMPIANS.* By Prof. R. HARKNESS, F.R.S., F.G.S.

[Abstract.]

THE area to which this paper referred is the tract lying between Stonehaven and Strathearn, including the south-eastern flanks of the Grampians for about two-thirds of their course. Metamorphic rocks, trap-rocks, the Lower and Middle members of the Old Red series (the former being sandstone, and the latter conglomerate), are the constituent rock-masses of the district, and give it its peculiar physical features. The mode in which these rocks are associated is well exhibited in the section on the coast (at Stonehaven), and in the several sections in the interior where streams lay bare the rocks. Sections at Stonehaven, Glenburnie, Strathfinlass, North Esk, West Water of Lethnot, Cruick Water, South Esk and Prosen, Blairgowrie, Dunkeld, Strathearn, and Glenartney, were described in detail.

Against the north-westerly dipping metamorphic schists (which sometimes include conformable limestones) come purple flagstones, but usually separated from them by trap-rocks, having the same strike. These flagstones pitch to the south-east, but retain a high angle away from the schists, and, in many places, are intercalated with beds of trap. The lower purple flagstones are unfossiliferous; but higher up tracks of Crustaceans (*Protichnites*) have been discovered by the Rev. H. Mitchell. The grey fossiliferous flagstones of Forfarshire succeed, still with a steep dip. Conglomerates succeed, in beds having a less inclination, gradually becoming more and more horizontal as they reach the low country.

The axis of the elevation of the Grampians thus appears to be along their southern margin, and to be marked by the trap-rocks separating the metamorphic schists and the purple flagstones of the Old Red series, and giving the latter their general south-easterly dip. As the metamorphic rocks of the Grampians have not yielded any fossils, their relation to the other old rocks of Scotland is difficult to determine.

3. *On the OLD RED SANDSTONE of the SOUTH OF SCOTLAND.* By ARCHIBALD GEIKIE, Esq., F.G.S., of the Geological Survey of Great Britain.

[PLATE XVIII.]

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Introduction.—During the last summer, while carrying on the Geological survey of the Lammermuir Hills, I was particularly

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struck with the number of felspathic dykes by which the Silurian strata of that region are intersected. It was my wish to ascertain, if possible, the probable date of these igneous rocks; and for this purpose it became necessary to determine the exact relation between the Old Red Conglomerates and Sandstones of East Lothian, and the Old Red Sandstone and Upper Silurian in other parts of South Scotland. I soon perceived, however, that the determination of this point had a much wider range than at first sight appeared, and that in truth it bore directly upon the question of the true classification of the Old Red Sandstone. The district which promised to afford the most satisfactory results was the Parish of Lesmahago, where, according to the section by Sir Roderick Murchison*, an ascending series could be made out from the Upper Silurian, through the Old Red Sandstone, into the Carboniferous group. I visited Lesmahago, and mapped the boundary-lines of the Lower Old Red Sandstone and Carboniferous rocks over an area of from 80 to 90 square miles. The results of this examination, in so far as they bear on the Old Red Sandstone, form the first and principal part of the present communication. I shall next refer to the extension of the Lesmahago features to the north-east, across the area of the Pentland Hills, into East Lothian and Berwickshire, and then point out some of the bearings of the facts adduced upon the physical geology of Southern Scotland during the Old Red Sandstone and Carboniferous periods.

LESMAHAGO†.

Silurian.—The basement-rocks of the Lesmahago district consist of a series of shales and flaggy sandstones belonging to the Upper Silurian. They form an anticlinal axis in Nutberry Hill, whence they strike south-west for six miles to beyond the village of Muirkirk in Ayrshire, when they are overlapped by Carboniferous sandstones. At Nutberry Hill, notwithstanding the contorted character of the strata, this axis is sufficiently well-marked. Southwards, however, its regularity is obscured, partly by a large intrusion of felstone, partly by faulting, which possibly took place prior to the deposition of the Carboniferous rocks, and partly by the way in which these rocks overlap and conceal those of older date.

Another Silurian patch occurs in the Haughshaw Hills as the centre of another anticlinal axis. In both cases it is plain that the present exposure of Silurian strata in this region, so far removed from the great Silurian tract to the south, arises from the flexured character of the country, and the subsequent denudation of the ridges. It is interesting to observe that the axis of these flexures

* Quart. Journ. Geol. Soc. vol. xii. p. 17.

† The numerous notes which I made of the details of the geology of Lesmahago may possibly form the subject of another paper. I need not refer here to previous writers on the Lanarkshire and Ayrshire rocks, as my present subject is a special one, which their labours have not anticipated. I may remark, however, that the general geology of the district is already sketched in Sir Roderick Murchison's succinct memoir on Lesmahago Parish, Quart. Journ. Geol. Soc. vol. xii. p. 15.

is from N.E. to S.W., that is, parallel to the general strike of the country. That other Silurian anticlines will be found in other parts of this district, seems in the highest degree probable; and hence we may anticipate fresh harvests of organic remains from the prolongation of the *Pterygotus*-bearing shales of the Logan Water.

Lower Old Red Sandstone.—The Silurian strata, as was clearly pointed out by Sir R. I. Murchison*, graduate upwards into a perfectly conformable series of red shales, sandstones, and conglomerate-bands, which pass by alternations into a higher and very thick group of purplish-grey sandstones, often pebbly and conglomeratic. The whole series above the highest of the Silurian shales must be many thousand feet thick. That it represents the lower, and perhaps part of the middle Old Red, seems to be indicated with sufficient clearness by the geological horizon and the petrological aspect of the strata. Through the kindness of — Brown, Esq., of Lanfine, I am in possession of confirmatory evidence. He informs me that in the sandstone-quarry of Lanfine, near Newmills, Ayrshire, several specimens of *Cephalaspis* have been found, some of which are in his cabinet. A drawing of one of these was sent me; it is a well-preserved buckler of *Cephalaspis Lyellii*. The Newmills sandstones form a part of the great series which stretches eastward by Lesmahago and the Clyde, towards the confines of Peeblesshire; and there can be no doubt, therefore, that the whole belongs to the Lower Old Red Sandstone.

The Lower Old Red strata, as developed in the neighbourhood of Lesmahago, present many points of interest, into which, however, I do not enter at present. There is but one feature to which it is necessary to advert, viz. that both Silurians and Old Red Sandstones are everywhere traversed by dykes of porphyritic felstone, often of considerable size. These dykes, so far as I have been able to observe, never intersect the Carboniferous series. I have seen only a single instance (that of the Nethan section, near Kerse) where the Carboniferous strata are in contact with a felstone-dyke; and there the former, in place of showing any trace of metamorphism, present an unaltered felspathic paste, in which are imbedded fragments of the subjacent dyke. All the felspathic dykes, therefore, appear to be older than the Carboniferous, and later than the Old Red rocks of the district.

Another series of dykes deserves incidental notice here. They consist of greenstone, and are found traversing all the other rocks of the district, igneous and sedimentary, as well as several large faults, without undergoing any deflection. They preserve their course in parallel lines from S.E. to N.W., across mountain and valley, at nearly right angles to the general strike of the country. Of course they are the latest rocks of the neighbourhood.

The town of Lesmahago stands on a narrow isthmus of Lower Old Red Sandstone, which expands westward into the bare heathy uplands of Ayrshire, while to the east it swells out into the fertile

* *Loc. cit.*

undulating region in which lies the valley of the Clyde. The narrowness of the band at Lesmahago arises from the southward prolongation of the great Lanarkshire coal-field, and from the northward extension of the smaller coal-field of Douglas. That these two coal-fields were at one time connected down the valley of the Nethan, and that thus a continuous band of Carboniferous strata stretched away north from Douglas to beyond Glasgow, can hardly, I think, be doubted; and this circumstance becomes of the highest importance in any endeavour to ascertain the true relation of the Carboniferous to the Lower Old Red Sandstone throughout the south of Scotland.

In the Birkenhead Burn, the Logan Water, the Blaeberry Burn, and the Greenock Water, there is a clear passage of the green Silurian shales into the red shales, sandstones, and conglomerate-bands of the Old Red series. That series dips regularly away from the Silurian axis of Nutberry and Priesthill on the north and north-west sides. On the east side, however, as already remarked, the succession is not quite so clear, owing to a fault which throws down the red sandstones against a low part of the Silurian series. This fault seems to increase in the amount of throw as it passes to the south-west. It appears to be overlapped by another tongue of Carboniferous rocks forming the north-eastern prolongation of the Muirkirk coal-field*. Starting, however, from the section on the Logan Water, where the whole succession is very clear, and passing north-eastward by Lesmahago to the Clyde, we find the purplish-grey sandstones which form the whole of that tract dipping almost uniformly E. by N. at from 25° to 45° . There is thus an ascending series for eight miles, the total thickness of which must be at least 12,000 feet, and is probably more. Again, along the north flank of the Haughshaw Hills, which consist of the same sandstones, the dip is still easterly. Their south flank is obscured by another fault, which has tilted on end both the Old Red and the Carboniferous beds. In the middle of the hills the Silurian shales come up in an anticlinal bend as at Nutberry Hill, and are well shown along the sides of the reservoir at Parishholm, and also in the lower part of the Parishholm Burn. The axis which they form seems to run on the east side of that streamlet, and nearly parallel to it. But the Old Red and Silurian strata in this part of the district are much disturbed. As we ascend the stream, the sandstones and shales near the base of the Old Red become twisted, vertical, and broken, and this character continues until the whole passes under a thick unconformable series of white Carboniferous sandstones forming the crest of the Cairn Table ridge, and dipping W. by N. at 13° – 20° .

Viewed as a whole, therefore, we have in the Lesmahago district two N.E. and S.W. Silurian axes, each with an encircling zone of Lower Old Red Sandstone. Their south-western prolongation is hidden by Carboniferous strata; while towards the north-east they

* Without a re-examination of this part of the district, I am unable to say decidedly whether the Carboniferous rocks here overlap the older strata, or are faulted against them. At present I incline to the former opinion.

gradually disappear, and the Old Red Sandstone then begins to form an ascending series towards the Clyde, the prevailing dip being E. by N.

Carboniferous.—I have referred to the tongue of Carboniferous strata which diverges from the great Lanarkshire coal-field, and extends up the valley of the Nethan to within a mile of Lesmahago. The Douglas coal-field stretches north to nearly the same distance from the town, and then bends south-westward between the channel of the Nethan and the base of the Haughshaw Hills. It becomes greatly attenuated in the Upper Monkshead Valley, and appears indeed to thin off entirely for a short distance. But a fault, which crosses the glen opposite the farm-house, throws the limestones and coals in again along the west flank of Hareshaw Hill, where the black-band ironstone was once extensively mined. From this point the Carboniferous rocks expand into the Valley of the Ayre, and up to the summit of the hills by which that valley is bounded on the south. Here and in the Douglas coal-field, although the surface often shows little else than a wide expanse of barren moorland, it nevertheless conceals mineral deposits of great value; and hence districts which a few years ago could boast only a few widely scattered hamlets, are now becoming dotted with chimneys and traversed by railroads.

A careful working-out of the details of the Carboniferous system as developed in the Lesmahago district would doubtless amply reward the labour. Especially full of interest are the alternations of marine and terrestrial strata, the disappearance of certain beds over particular areas, and the thickening and thinning of coals and limestones, as well as shales and sandstones in particular directions. Some of these appearances obtain, I believe, their true explanation in the unconformable relation of the Carboniferous to the underlying Red Sandstones to which I shall immediately advert. My observations among the Carboniferous strata were almost wholly confined to the lower limestones and the beds below them—in short, to the base of the Carboniferous series where it rests on the Old Red. The features of the junction-line I shall now proceed to describe.

In no part of the district can the junction of the Carboniferous and Lower Old Red Sandstone be more clearly made out, than along the southern margin of the Auchenheath coal-field, about a mile north of Lesmahago. By descending the streamlet called Kerse Gill, which skirts the south side of some lime-quarries and falls into the Nethan below Kerse House, we obtain a good section of both formations. Near the bridge south of Kapeshall, Old Red Sandstones are seen dipping 45° E. of N. at 25° – 30° . The same series can be traced down the channel of the stream for fully half a mile, the general dip being E. by N. At the bridge above the lime-quarries, the sandstones are mottled, purple, and white, flaggy and micaceous, traversed by two small felstone-dykes. Below this bridge, the sandstones continue with the same dip, but are much whiter—so white, indeed, that at first, I doubted whether they were not Carboniferous. It was not long, however, before I satisfied myself that they really

belonged to the Old Red series. Below these pale sandstones, no rock is visible in the streamlet for some way, until at last we come to Carboniferous sandstones, shales, and limestones, full of fossils, dipping northerly at 5° – 10° . These occupy the bed of the Burn for a short distance, when the dip changes to W., and they then sweep round the west side of the Nethan Valley, as far down as the foot-bridge, where they cross the river and ascend the valley on the east side. Their boundary-line then turns sharply round to the north, skirting the side of Black Hill, and curving round the north end of that hill, down into the vale of the Clyde near Crossford. By comparing the line now described and its attendant dips with the strike of the Old Red Sandstones, it will at once be seen that the one is as nearly as may be at right angles to the other. The Red Sandstones dip steadily eastward at considerable angles, while the Carboniferous undulate gently to the north and north-west. It cannot for a moment be held that any fault intervenes between the two formations; for the sinuosity of the junction-line and the undisturbed position of the Carboniferous beds forbid such an explanation.

There is only one locality in this part of the district where the actual base of the Carboniferous series is seen. It is in the channel of the Nethan, below the foot-bridge already referred to, where a set of Carboniferous sandstones, with large stems of *Lepidodendron* and *Sigillaria*, graduates downwards into a conglomerate, resting on a porphyritic felstone in the Old Red series. These dykes of felstone, as I have already remarked, never cut through Carboniferous strata. It is presumable, therefore, that they are older than these. But in the present instance, not only does the igneous rock not penetrate the Carboniferous conglomerate, but the conglomerate is really to a considerable extent formed out of the felstone, since its paste in the lower part is highly felspathic, and contains moreover distinct fragments of the peculiar rock on which it rests. The larger number of fragments composing the conglomerate consist of the whitish sandstone which I have described as occurring at the Kerse Gill. Hence, though we cannot see here the Carboniferous series actually resting on Old Red Sandstones, we yet find it formed partly out of the latter and partly out of igneous rock, which was intruded into the older series before the deposition of the Carboniferous group.

The evidence from the flanks of Black Hill is very satisfactory. That hill consists of an enormous protrusion of porphyritic felstone, having a general bedded form on the great scale, and dipping to the east along with the Old Red Sandstones among which it has been intruded. It is underlaid by hard purplish-grey sandstones, which can be seen at different points towards the south end, dipping E. by N. at from 20° to 30° . On the east side of the hill similar sandstones supervene; they are admirably shown in the channel of the Clyde, where the dip is still easterly, at from 30° to 45° . It is on the truncated ends of these sandstones that the sandstones, shales, and limestones of the Carboniferous series have been deposited.

Nothing can be clearer than the general relation of the rocks along the west flank of Black Hill. The coals there have been

worked up to the felstone; and the underlying limestones do not for some distance come to the surface. In short, we cannot but perceive that when the Carboniferous series was being formed, the west side of what is now Black Hill existed as a precipitous cliff-line, along the base of which the deposits accumulated, and that consequently the Lower Old Red Sandstones must have been tilted up and subjected to an extensive denudation before the beginning of the Carboniferous series in this neighbourhood. The section, fig. 1, Pl. XVIII., represents the visible relation of the rocks in this part of the district.

The unconformity which I wish to establish is so clearly indicated in the Kerse section, that this section might be held as decisive for the entire district. But it may be well to cite another instance, which occurs at a distance of twelve or thirteen miles S.W. from Kerse in the parish of Muirkirk in Ayrshire.

The Silurian shales which occupy the higher part of the Nethan and Pockmair Burn cross over the ridge of hills that divides the two counties of Lanark and Ayr, and stretch for five or six miles to the south-west. In the neighbourhood of Priesthill the beds are inclined at a gentle angle to the north-west. As they strike south-west, however, the angle becomes greatly higher, and (at least in the bed of the Greenock Water, below Mansfield) the beds become quite vertical. This high inclination continues for rather more than a mile, until, a little below the farm-house of Burnfoot, the vertical Silurians and a large felstone-dyke which traverses them are overlapped by Carboniferous sandstones dipping a little S. of W., at 8°. The unconformity here is of the most violent kind; for it consists of a vertical series overlaid by a nearly horizontal one. These Silurians form a part of the Nethan series, since as we trace them northward along the Greenock Water the dip lessens, and they are eventually succeeded by the red shales of the lower Old Red group. The general relations of the rocks in the upper part of the Ayr Valley are shown in the section (fig. 2).

The Cairn Table ridge, part of which is crossed by this line of section, shows the same superposition of gently inclined Carboniferous sandstones upon a disturbed and vertical Silurian and Lower Old Red series.

Again, the boundary-line of the Douglas coal-field corresponds in its general features to that of the Auchenheth coal-basin north of Lesmahago. The general dip of the Carboniferous rocks there is away from the Old Red Sandstones, which, skirting the basin, are usually inclined to the east. A fault running along the Nethan Valley from the Trows to Cumberhead has greatly disturbed the Carboniferous limestones along its course; but the connexion of the different rocks, after other parts of the district have been visited, is nevertheless quite apparent. If we could restore the strata here to their normal position, we should find the same unconformity as in other parts of the district; for no sooner does the fault die away to the north-east than the unconformity becomes at once apparent. At Boghill and Porcheck, for instance, the Old Red sandstones are seen dipping easterly at 25°; while immediately to the south the Carboni-

ferous limestone is quarried at Auchtool dipping S. by E., that is, almost at right angles to, and along the denuded edges of, the Old Red Sandstone bank to the north.

Sufficient evidence has probably now been adduced to prove that, in Lanarkshire and Ayrshire, strata belonging to the Carboniferous Limestone series rest unconformably upon certain sandstones and shales of Lower Old Red and Silurian age. Some of the features of this unconformity must be briefly noticed.

One of the first facts which struck me when I began the examination of this district was the entire absence of the vast mass of strata below the Carboniferous Limestone, known in the Lothians as the Lower Carboniferous group and the Upper Old Red Sandstone. I had traced these strata from Mid-Lothian down into Lanarkshire, not more than 15 miles distant from the district under review, and I therefore looked to meet with them below the Carboniferous Limestone of Lesmahago; but they do not exist there.

Another feature which soon presented itself was the fact that, taking as a line of measurement a certain bed of marine limestone the outcrop of which is tolerably well known, the thickness of beds between the limestone and the underlying red sandstones varied considerably throughout the district. Thus at Auchtygemel, the section on the Nethan shows a depth of Carboniferous strata below the limestone of perhaps less than 100 feet; while along the margin of the Auchenheath basin generally, the thickness appears to be always below 200 feet. At the bend of the Nethan below Gateside, these strata are (I quote from memory) somewhere about 50 or 60 feet. At Hallhill, on the west side of Black Hill, the limestone comes to rest directly on the Old Red and its associated porphyry; and the same seems to be the case at Auchmeden. From this latter locality, however, as we trace the limestones to the south-east, there gradually intervenes between it and the Old Red an increasing thickness of white and reddish sandstones. These are well exposed in a series of quarries on the top of a wooded eminence called Stone Hill, in Carmichael Parish. From where the Old Red series is covered by the Carboniferous sandstones south of Drumaben, to where the limestone crops to the west of Stone Hill, is rather more than a mile; the angle of dip at the quarries varies from 20° to 25° , while at Drumaben it is only 8° : but taking it at an average of 15° , the thickness of strata between the limestone and the Devonians will probably be more than 1000 feet. I had not an opportunity of ascertaining how far these beds extend southwards.

The other side of the Douglas coal-field, skirting the south-east flank of the Haughshaw Hills, is bounded by a marked N.E. and S.W. fault, whereby both the Carboniferous and Old Red series are tilted on end. Though I did not ascend the Carmacoup and Kinnick Waters, I had little doubt that this fault was thinning away to S.W., and that the same series of sandstones which occurs at Stone Hill would be found at the head of these streams stretching westward into Ayrshire. When on the top of Cairn Table, it seemed to me highly probable, from the contour of the hills, that the grey Carboniferous

sandstones which cap the Cairn Table ridge also occur along the hill-tops to the eastward, and hence they would range by Kinnickfoot into the Douglass coal-field.

It appears, therefore, that the Old Red Sandstone and Silurian hills to the south are flanked by a thick series of Lower Carboniferous sandstones, but that a short way northward, as we advance in the direction of the great coal-fields, this series thins rapidly away to about 50 or 60 feet in some places. Even at their greatest thickness, however, these sandstones but poorly represent the enormous depth of Lower Carboniferous and Upper Old Red sandstones in the Lothians and Berwickshire.

The lithological aspect of the base of the Carboniferous group in the Lesmahago district varies considerably in different localities. Along the southern line, where the thick Lower Sandstone series occurs, the basement-beds are reddish and conglomeratic. In the Monkshhead Glen they are very red, marly, and sandy, with fronds of a *Sphenopteris*. At Glenbuck they consist of hard, reddish-grey, false-bedded sandstones. Below Kerse on the Nethan, the lowest bed I have already described as a conglomerate formed partly out of pale Old Red Sandstone, and partly out of a whitish porphyry-dyke on which the conglomerate at the point of section rests. In short, towards their base the Carboniferous rocks assimilate in general aspect to the Old Red Sandstones below. This resemblance is sufficiently close to lead one at a first glance into the belief that there is a gradual passage of the one series into the other. But the peculiar purplish-grey or chocolate colour and the fissile flaggy structure of the Old Red sandstones never, so far as I have seen, shade into the brick-red hue and false-bedded character of the Carboniferous rocks.

Finally, from what has been stated above, and from the accompanying Map, it will be seen that the base of the Carboniferous series rests successively upon many different horizons, alike of the Silurians and the Lower Old Red Sandstones. Such a transgressive line shows very clearly the unconformable relation of the Carboniferous beds to the older strata on which they lie.

Pentland and Lammermuir Hills.—Having ascertained that between the Carboniferous Limestone series and the Lower Old Red Sandstone there existed in Lanarkshire and Ayrshire a decided unconformity, I knew from previous examination that the same physical break must occur between the Upper and the Lower Old Red Sandstones. With the experience of the Lesmahago sections, I again visited the Pentland Hills, in company with Professor Ramsay, and found that the localities mutually explained each other.

In the memoir to accompany sheet No. 32 of the Geological Survey of Scotland, I have described in detail the structure of the Pentland Hills. It is only needful to mention here that the richly fossiliferous shales of the Upper Ludlow rock of that locality are overlaid by conformable red shales, sandstones, and conglomerate-bands which, there seems no reason to doubt, correspond to the similar series of

beds which at Lesmahago form the base of the Lower Old Sandstone. These Silurian and Old Red shales are covered unconformably by a thick group of sandstones and conglomerates forming the Upper Old Red Sandstone, and the Lower Carboniferous or "Califerous Sandstone*" series of the Lothians. (Fig. 3.) Here, then, we find part of the great series of strata which is wanting at Lesmahago. We see too that, just as at Lesmahago, there is a strict stratigraphical succession through the Upper Silurian and the Lower Old Red Sandstone of that district; so at the Pentlands there is an equally perfect sequence through the Carboniferous and Upper Old Red Sandstone. The line of physical break occurs, therefore, in the Old Red Sandstone. The upper part of that formation graduates upward into the Carboniferous series; the middle and lower portions pass down into the upper Silurian; and between these two graduating series there is in the Pentland Hills, as in Ireland, a well-marked and even violent unconformity.

As the southern districts of Scotland become more thoroughly explored, more especially to the south-west, the area of Lower Old Red Sandstone and Upper Silurian strata will probably be greatly enlarged; and I have little doubt that the same unconformable relation will everywhere be found to characterize the junction of the Carboniferous and Upper Old Red Sandstones with the older rocks.

There is, however, one other area of Upper Old Red Sandstone south of the Forth to which I would advert,—that of East-Lothian and Berwickshire. The flanks of the Lammermuirs are encircled by a more or less continuous zone of red sandstone and conglomerate, resting unconformably on inclined Lower Silurian shales and grits. These strata pass insensibly upwards into the Carboniferous series; as, for instance, along the coast at Cockburnspath, and in the neighbourhood of Dunse. Below the passage-beds, the thickness of this Old Red series is sometimes very considerable. Thus, along the eastern end of the hills, the great conglomerate south of Dunbar must be at least 1500 or 2000 feet thick; and, though the greater part of this conglomerate is representative of the sandstones and marls of other parts, there is still a considerable depth of sandstones between its top and the passage-beds into the Carboniferous series.

In the red sandstones of this district, fossils have been found in several localities.

The late Dr. Fleming informed me that he had found scales of *Holoptychius* in the red sandstones of Siccar Point, that is, not far from the base of the Carboniferous series. Similar scales and teeth were found many years ago by Mr. Stevenson in the equivalent sandstones in the neighbourhood of Dunse†. I have myself found them in considerable abundance along with much-mutilated remains of plants; and Mr. Stevenson informs me that a very perfect specimen of *Cyclopterus* was found in the same neighbourhood some years ago.

* *Califerous Sandstones*, the name given by Mr. M'Laren to the great sandstone series below the Carboniferous Limestone of the Lothians.

† It seems very certain, however, that these remains are not those of *Holoptychius*. They strongly resemble some which have been assigned to *Asterolepis*.

There can be little doubt, therefore, that the red sandstones, marls, and conglomerates of the south-east of Scotland are the representatives of the "Dura Den Yellow Sandstones," and the "Upper Old Red" of Ireland. They differ very widely in aspect from the Lower Old Red sandstones of Lesmahago; and if these sandstones were present in Lammermuir, they would be found to be covered as unconformably by the Old Red conglomerates and sandstones of East Lothian and Berwickshire, as, a few miles to the west, they are by the Old Red and Carboniferous conglomerates and sandstones of the Pentland Hills.

In short, throughout the whole of central Scotland the Upper or Holoptychius-beds of the Old Red Sandstone are found to graduate by almost imperceptible stages into the Lower Carboniferous series. The two formations form one great lithological whole; and we can in general define their mutual limits on the map only by an arbitrary shaded line. But they are both strongly marked off from the great series of chocolate-coloured sandstones of Lanark and Ayrshire, alike in mineralogical, stratigraphical, and palæontological aspect. That series graduates downward into the Upper Silurian, with which it forms one continuous whole; and between these two formations and the two former, occurs the great physical break above described. In fine, the Upper Silurian and the Lower Old Red Sandstone of south Scotland form physically one connected group, the Upper Old Red and Carboniferous form another, and the two groups are everywhere separated by a marked unconformity.

Physical Geography of South Scotland during the Old Red Sandstone and Carboniferous periods.—The facts presented in this paper seem to afford some indication of the contour of the southern part of Scotland during the accumulation of the Old Red Sandstone and Carboniferous series.

At the commencement of the Upper Old Red period, the Silurian and Lower Old Red Sandstone had been considerably altered from their original horizontal position. In the district of the Pentland Hills the disturbance amounted even to verticality, while in Lanark and Ayrshire it consisted of a series of gentle anticlinal folds, which, however, seem to have been materially increased in inclination during subsequent periods. Probably more or less in connexion with this disturbance are the numerous and often extensive protrusions of felspathic rocks which intersect the tilted strata. Much additional light requires to be thrown on these changes, as well as on others which may have taken place during the interval represented by the unconformity above described. At present we know little more than that the disturbing movements had ceased before the commencement of the Upper Old Red Sandstone.

It was on the uneven surface left by these movements, that the Old Red conglomerate and sandstones of the Lothians and Berwickshire began to be thrown down. I think there is good evidence to prove that, when this period began, the great Silurian region of South

Scotland stretched away from south-west to north-east as a long island, indented by narrow inlets and curving bays. Some parts of the coast-line were low and sandy ; but a large portion seems to have resembled the existing coast at St. Abb's Head, and to have risen as a perpendicular cliff-line worn into clefts and stacks, and deep ocean caves. The sea probably ran in broad sounds between this island and the Cumbrian mountains on the one side, and the southern flank of the great Grampian chain on the other.

From the commencement of the Upper Old Red and onwards through the Carboniferous, the land underwent a process of subsidence, which, though in its later stages often retarded and even reversed, yet continued the dominant movement in this part of the country.

As it went on, the long Silurian and Lower Old Red island became narrowed in outline, the bays on either side advanced nearer to each other, until by degrees they met, and the main island merged into an archipelago. The stages of the subsidence, in so far as they can be made out in the region of Lammermuir, will shortly be described in the Memoirs of the Geological Survey. What I more especially wish to point out at present is, that from the facts presented in this paper we were led to notice that the west part of the island continued above water long after the eastern part had become submerged. That area which now forms the southern portion of Lanarkshire and Ayrshire, perhaps along with much of the adjacent district, continued to be land when the site of the Lothians and Berwickshire had sunk below the sea and become covered over with many thousand feet of sedimentary matter. It was not until the whole of the Upper Old Red Sandstone, and nearly the whole of the Lower Carboniferous group had been deposited, that the bases of the Loosmahago Hills were washed for the first time by the waves of the encroaching sea. Either, therefore, the south-western district of Scotland must have stood several thousand feet higher than the south-eastern, or the rate of submergence must have been greatly more rapid over the latter area than over the former.

It would be premature, without many more additional details, to decide which of the two suppositions is the true one, although a difference in the rate of submergence seems at present best to explain the facts. There are also other points connected with the ancient physical geography of southern Scotland on which I much wish to touch ; but I must delay their consideration until I am able to lay before the Society the results of another visit to the uplands of Peebles and Lanark.