V.—ON THE SILURIAN ROCKS OF THE COUNTIES OF ROXBURGH AND SELKIRK.¹

By C. LAPWORTH and JAS. WILSON.

FOR the last three summers we have devoted the greater part of our leisure time to the examination of the Silurian Rocks that lie more immediately between the Moorfoot Hills and the English border. Our investigations have been attended with a fair amount of success, and we thought that a short summary of what we have accomplished would not be wholly uninteresting to the Geological Section. As these old Silurian strata of the South of Scotland have only been once alluded to in the papers already read at the Meeting—namely, by the Chairman in his eloquent address—we may be pardoned if we say a few preliminary words concerning them.

These Silurians fill up almost the whole extent of Scotland that lies to the south of the great central Carboniferous basin, and stretch uninterruptedly from sea to sea, forming the largest area of unaltered Silurian in the British Isles. The investigation of these rocks is attended by almost insurmountable difficulties. In the district to be described, the beds are folded and contorted in the most remarkable manner, so that it is possible to walk for a mile across the dip where the rocks are well exposed—as, for instance, in the beautiful glen of the Yarrow, below the old peel of Newark—without ascending or descending more than three hundred feet in the order of the beds, and this, when the rocks are pitching at angles, varying from 80° to the perpendicular. All these old strata have pretty much the same lithological character throughout; there are no limestones, scarcely any conglomerates, and only one constant easily recognizable bed among them; and not only so, but previous to our labours, scarcely any fossils had been discovered, except in a few isolated spots, from which the age of these ancient sediments could be determined. With all these difficulties in the way of their investigation, there can be no wonder that these rocks have been neglected by geologists for the younger and more promising formations, and that the Government Geological Survey have been forced to colour all the beds of this district already surveyed of a uniform purple tint. Nevertheless, much has already been done, and well, and the well-known names of Murchison, Nicol, Harkness, and Geikie, are only the first of a long array of those who have laboured long and devotedly among them.

Small portions of the district more particularly examined by us were described by Professor Nicol, in papers read before the Geological Society of London, and published in volumes iv. and vi. of their journal.

He discovered *Graptolites Griestonensis* (Nicol), *G. Sedgwickii* (McCoy), and *G. priodon* (Brown) in the Grieston Slates, and a peculiar form he called *Graptolites laza* in the Thornilee Quarry. He mentioned the fact of dark schists with carbonaceous markings

¹ Read before Section C of the British Association, Edinburgh.

occurring in the flanks of Ernton Fell in Liddesdale, and, arguing from lithological characters alone, considered that some of the beds to the south of Hawick were of Upper Silurian age; but in a section exhibited by him at the meeting of the British Association at Belfast in 1852, and afterwards published in Sir Roderick Murchison's *Siluria*, he relinquished this opinion, and held that the Southern beds were of the age of those associated with the Moffat Anthracite.

The Geological Survey of Scotland published maps and explanations of much of the northern portion of the district. In Berwickshire, *Graptolites priodon* was discovered at Byrecleuch, in Headshaw Burn black shale with *Dip. pristis*, and also on the sides of Browbeat Rig, in Peeblesshire. No evidence was, however, obtained by which the strata could be split up, and the whole of the Silurians mapped were coloured in one uniform tint.

This is the sum of what was known of the district before we began our investigations, and that which is additional in this paper is mainly the result of our own labours.

In an able, and at that time exhaustive paper on the Silurians of South Scotland, by Professor Geikie, published in the third volume of the Transactions of the Geological Society of Glasgow, the following sub-divisions of the strata were recognized:—

1. The purple schists of Eskdale-muir.
2. The thin bedded flags of Glenkiln, etc.
3. The greywackes and shale of Moffat.
4. The thick grits of the Broad Law and Innerleithen.
5. The Wrae and Winkstone beds.
6. The blue grits and shales bordering the great Carboniferous basin.
7. The Girvan beds.
8. The upper Silurians of Kirkcudbright.

Our divisions are in effect the same as those of his. Our plan, however, has been to name the several groups of strata after the towns near which they attain their greatest development, and thus we have in our country:—

1. The Hawick rocks.
2. The Selkirk beds.
3. The Moffat series.
4. The Gala group.
5. The Riccarton beds.

Nos. 1, 2, 3, answer to Professor Geikie's divisions 1, 2, and 3 respectively. The Gala group embraces his divisions Nos. 4, 5, 6, and possibly also the greater part of No. 7, while the Riccarton beds are the exact equivalent of his No. 8.

It is well known that these Silurian beds of South Scotland dip away from an anticlinal line that runs in a N.E. direction from Dumfries to Berwick, and that the rocks lie, as a whole, in an ascending order as we proceed in a N.E. or S.W. direction at right angles to this line.

Taking advantage of this fact, we will briefly describe the strata

as they occur in this way, first to the north, then to the south, of this axis :—

1. *The Hawick Rocks.*—The great anticlinal and the beds for a few miles on either side consist in this district of very arenaceous grey and purple sandstones and schists. The purple colour is most conspicuous in the west between Dumfries and the dreary uplands of Eskdale-muir, but dies almost entirely to the east, where we find the prevailing tint is a dull brownish grey. These strata are best seen on the hills to the north of the town of Hawick, where their upturned edges, which are singularly bare of soil or clay, have been cut and carved by the old ice-sheet into narrow streamless valleys, sometimes closed at one end by an abrupt cliff of rock overhanging a lonely tarn.

Professor Harkness found the track of a Crustacean in these beds at Binks, a few miles to the south of the axis. We have ourselves detected *Protovirgularia* and *Annelides* within a mile of it; but our friend Professor Elliot of Goldielands, who has devoted himself to the careful investigation of these strata, has met with much greater success, and has procured specimens of worm-tracks, *Arenicolites*, *Protichnites trichoides*, rain prints, ripple markings, and those peculiar forms called plants by some of the American geologists, in great variety and abundance.

These ancient rocks bear a strong resemblance both in their lithological characters and in their fossil contents to the Cambrians of the Longmynd, but they are very probably of later age.

2. *The Selkirk Beds.*—As we proceed farther from the axial line, the arenaceous character of the rocks is gradually lost, and we pass insensibly upward into a great thickness of fine grained grits, flags, and shales of a very light grey or greenish colour. The whole of the beds are much crumpled and jointed. The thicker strata are usually veined with calc-spar, some of the veins being more than a foot in thickness. Almost every joint is coated with the same substance, and this gives the whole set of strata a very peculiar appearance. These rocks cover a large tract of country to the west of the Hawick rocks, which, however, gradually decrease as we proceed to the south-west, where we have found that the Selkirk and Hawick beds slowly die away to a point between the Upper Silurian and Moffat beds of Kirkcudbright.

We have only procured a couple of species of *Protovirgularia*, a Crustacean, and a few *Annelides* from these rocks; but the beds look very promising in places, and we expect a much richer harvest in the future.

3. *The Moffat series.*—Immediately to the north of the Selkirk beds, we reach another set of strata of a little more inviting appearance. It consists of thick and thin beds of greywackes and shales of a dark grey or greenish colour, often weathering, especially where a little altered, of a brownish or yellowish colour. The great feature of the series, however, is the bed of anthracitic shale at its summit. This band is of incalculable assistance to us in working out the order of this portion of the system, as it seems to be continuous from sea to

sea, and appears to retain very much the same characteristics throughout the whole length and breadth of the northern slope. It is beautifully developed in the neighbourhood of Moffat. In one place, stretching in an unbroken and slightly undulating line of ten or twelve miles, afterwards let down by little faults that cut it entirely out at irregular intervals; in a second, folded in such a way that the outcrop maps a number of sub-parallel inosculating lines; in a third, shown as a long fusiform patch peeping from a denuded anticline, or left snag in the hollow of a synclinal fold. The mineral character of this bed, the deep black shale loaded with graptolites, and the yellow or white mud-stones, all disfigured by stains of oxide of iron, so clearly mark the bed, that it is picked out at once from the surrounding strata. These shales and mud-stones, where they are unaltered, are easily destroyed by the elements, and their position is frequently marked by a deep red gash, conspicuous against the dark heather high up on the mountain side, and visible at a great distance. It is the metropolis of the Graptolites in Scotland, and is crammed with a great variety of peculiar species—the majority of them, in fact, being unknown in beds of later age.

In the St. Mary's Lake districts, the Douglas Burn, the Upper Tweed, and in the Holms Water, we ascertained that these beds come up again and again, and almost the whole of the country in that direction must consist of beds of Moffat age; but the ground they occupy in the district we are describing is comparatively small. We find them in two distinct areas—one to the north, the other to the south, of our Gala group. To the south, they succeed at once to the Selkirk beds, and contain a couple of lines of the anthracite band—one running from the rapids of the river at Ettrick Bridge for about four miles, till it is lost under the gravel of the Ettrick, near Selkirk; the second, emerging from below the Gala beds at Ettrickbank, is continued in a broken line through Lindean, the romantic dingle of the Rhymer's Glen, and Melrose, till it plunges beneath the Old Red Conglomerate near Leaderfoot. It thins out very rapidly, however, in this distance, being only about a few feet thick at its termination. We have detected in these bands a great number of the Moffat fossils, including:—

<i>Siphonotreta micula</i> , M'Coy.	<i>Cladograptus capillaris</i> , Carr.
<i>Aerotretra Nicholsoni</i> , Davidson.	<i>Heliocograptus gracilis</i> , Hall.
<i>Dicranograptus ramosus</i> , D. sextans, Hall.	<i>Diplograptus pristis</i> , His.
<i>Dicellograptus Forchhammeri</i> , Gein.	" <i>Whitfieldii</i> , Hall.
" <i>Moffatensis</i> , Carr.	" <i>vesiculosus</i> , Nich.
<i>Cladograptus linearis</i> , Carr.	<i>Chimacograptus teretiusculus</i> , His.

and a few other peculiar Moffat species, but the beds are usually so crushed and altered that they can only be procured in very small fragments.

The whole Moffat series then sinks below the Gala beds, afterwards to be described, and comes to the surface again along the northern edge of the Silurian.

We have found here three distinct lines of the anthracitic band running approximately parallel and pretty close to each other.

There is also another conglomerate made up of millions of little white quartz pebbles, very like that of the Winkstone Quarry, and which is traceable in four distinct lines to the north of the pebbly grit. This conglomerate contains both rounded and angular pieces of the Moffat shale, often full of its characteristic graptolites. Some of these fragments are much altered, and full of little quartz veins, and exactly resemble the little pebbles of the altered Moffat shale now found in the burns; proving that in some localities, at least, the anthracite beds must have been hardened into rock, upheaved, and greatly altered before this conglomerate was deposited. The first line appears to cap the Grieston slates throughout, the second runs across the hill tops between Fountainhall and the Luggate water, for a distance of six or seven miles. The third appears a little to the north of this, and at the cottage of Ladyside, and the fourth runs parallel with the anthracite down the south bank of the Heriot. There are also thin bands of carbonaceous shale that run on for many miles, more especially towards the bottom of the group.

The fossils of the Gala group include:—

<i>Diplograpsus palmeus</i> , Barr.	<i>Graptolithus socialis</i> (n. sp.).
" <i>bullatus</i> , Salter.	" <i>gemmatus</i> , Barr.
<i>Graptolithus priodon</i> , Bronn.	<i>Rastrites Linnæi</i> , Barr.
" <i>colonus</i> , Barr.	<i>Retiolites Geinitzianus</i> , Barr.
" <i>Sedgwickii</i> , M'Coy.	" <i>obesus</i> (n. sp.).
" <i>sagittarius</i> , His.	<i>Dictyonema</i> (sp.).
" <i>lobiferus</i> , M'Coy.	<i>Ceratiocaris</i> (2 species).
" <i>Salteri</i> , Geinitz.	<i>Aptychopsis</i> (2 species).
" <i>Griestonensis</i> , Nicol.	<i>Peltocaris aptychoides</i> .
" <i>Nilesoni</i> , Barr.	<i>Annelide</i> , such as <i>Crossopodia</i> .
" <i>turriculatus</i> , Barr.	<i>Nereites</i> , and many others.

The fauna is, as a whole, remarkably different from that of the Moffat series. About 9-10ths of the Graptolites of the anthracitic band have disappeared, the branching forms all extinct, and their place is usurped by the mono-grapsus, which is specifically unimportant in the Moffat beds. This change is very sudden, as nearly the whole of the peculiar Gala forms may be collected within a few yards of the anthracitic band itself, both in the neighbourhood of Galashiels, and apparently also on the Douglas water. The great alteration in the fauna cannot be due to a change in the condition of the sea-bottom, for the beds from which the lowest Gala species are obtained are black carbonaceous shales, of a foot or two in thickness, with an out-crop that seems to be continuous for nine or ten miles at a stretch.

The great majority of the Gala species run from the base to the summit of the group, proving the unity of the whole, but rendering it utterly impossible to subdivide the strata by means of the fossils.

For these and many other reasons, which time will not allow us to discuss here, we consider that the Gala group is a distinct and single division of the Silurian rocks, commencing immediately above the anthracite bed of the Moffat series.

One fact should here in honesty be stated concerning the Gala beds. The rocks of the group to the north of the Grieston slates have, as a whole, a different appearance from those lying to the south

of that line; but this needs much fuller investigation. At one time, we were of opinion that the Gala beds rested unconformably upon the Moffat rocks, but we have been compelled to give up this theory for the southern area at least; but there are many facts in the north that appear to us utterly inexplicable, unless we admit a slight unconformability or an overlap.

Returning once more to the great anticlinal from which we started, and proceeding thence up the strata as before, but this time in a southerly direction, we find the Selkirk beds coming in their proper place upon the Hawick Rocks, and containing *Protovirgularia*, *Phyllopoda*, and *Annedides*; but instead of the Moffat beds following them, we have a thick series of rock of quite a different aspect, which are called by us the Riccarton beds, and are of Upper Silurian age. We made the discovery in the spring of last year, and a paper by one of us upon the subject was read before the Geological Section of the British Association at Liverpool.

These rocks are found in five separate areas—

1. In the well-known tract of country to the south of the town of Kirkcudbright.
2. To the south of the granite area of Criffel and Dumfries.
3. In a long stretch of country extending from a point near Lockerby to the Old Red Sandstone near Stobbs Castle.
4. In a large inlier surrounded by Old Red Sandstone and Carboniferous, and reaching from the village of Oxnam, near Jedburgh, to Ernton Fell on the Liddel.
5. In a small patch at the head of the Kale Water, high up among the porphyries and limestone of the Cheviot Hills.

The northern boundary of these rocks seems to form an almost exact straight line parallel with the average strike of the Lower Silurian. It is very probably a fault, though we are unable to prove this.

The strata in these districts are lithologically identical with those of Kirkcudbright. They consist of grit and shale not unlike those of the Lower Silurian, but there are hundreds of little bands of carbonaceous schist full of Graptolites, always, however, in a very bad state of preservation. The whole set of beds are very calcareous, more especially the dark shales.

The fossils are—*Rhynchonella nucula*, *Orthoceras tenuicinctum*, *O. ibex*, *O. tracheale*, *Graptolithus priodon*, *G. colonus*, and *Flemingii*, together with many forms of *Phyllopoda*, etc., such as *Ceratiocaris* and *Aptychopsis*, and possibly *Pterygotus*. We have also found specimens of *Cyrtograpsus*, *Ptilograpsus*, and *Inocaulis*, genera new to Scotland.

Thus, in the country examined by us, there appears to be five distinct and separate groups of Silurian strata, the first two differing in lithological characters alone, none of the fossil forms found in them being of any value in estimating their age.

The superior groups, however, contain a great number of fossils, and their place in the Silurian system can be approximately ascertained. The number of species known to us has not been made up without a very large amount of labour and research. When it is re-

membered that the officers of the Geological Survey, with all their experience, mapped the whole of Haddington and the North of Berwickshire without detecting more than two Graptolites in the whole of the Gala beds of that district, and added but a single species in Peeblesshire to our Grieston Fauna—when it is known that the most careful examination of the large tracts is often entirely fruitless, and that the majority of the fossil beds only yielded up their remains after having been examined without result again and again—the interest and value of the fossils yet obtained is seen to be very great.

We have made out about forty species from the Moffat series, a little less from the Gala group, and only about a dozen as yet from the Riccarton beds.

An examination of these fossils shows us the enormous predominance of the Graptolites. These peculiar creatures have never yet received the attention they deserve, and those of Britain have been treated so carelessly that the real horizon of some of the species cannot be even guessed at.

Enough, however, is known of their localities in the North of England, in Bohemia, and in North America, to enable us to speak pretty confidently as to the range of many of the forms in the Silurian system, and to fix approximately at least the age of the Gala and Moffat formations.

It would greatly lengthen this paper were we to lay all the evidence before you in order, but it is sufficient for our present purpose merely to state the conclusions at which we have arrived.

A careful comparison of the Moffat Graptolites with those of other countries has convinced us that these beds should be classed with the Utica Slate and Hudson River Group of North America and the Graptolite-bearing schist of Wexford and Waterford; in other words, that they are of Bala age, or bridge over the gap between the Bala and Llandello.

The fossils of the Gala Group lead us to place it high in the Lower Silurian, and to believe that it is very probable that some of the higher beds are of Upper Silurian age. Its fauna approximates most closely to that of the Coniston mud-stones of Cumberland and Westmoreland, and which are placed by the Geological Survey of England at the base of the Upper Silurian; it has also a very close relationship to that of Barrande's Colonies and the band E. e. 1, the last of which is also classed with the Upper Division.

Such, then, is a summary, as short as we can make it, of the work already done by us in these old sedimentary deposits; very little, it is true, in comparison with what yet remains to be done in the future, but enough to encourage us to persevere.

We have purposely abstained from comparing the structure of this district with that further to the west, leaving the task to those who are more familiar with that country. We believe that our subdivisions (which are those into which our strata naturally fall), for this district at least, will, in effect, ultimately be adopted. We hold that our Upper Groups can be separated from each other, even

lithologically, but more certainly and effectually by their fossils, which our paper shows only need a little extra perseverance to be detected almost everywhere. It may be urged that if we draw the lines of separation at the horizons mentioned, these boundaries will have as strange an appearance on the map as a diagram of the contortions to which their irregularities are due. But for the purpose of science, the strata must be separated, if not in the present, then in the future, and wherever the divisional lines may be drawn, the same difficulties will occur.

One thing is plain from the large list of fossils we have discovered—all that is necessary is careful untiring work amongst these strange old strata, and these will in time fall into their proper groups, and form as grand and interesting a series as the typical Silurians themselves.

NOTICES OF MEMOIRS.

L.—ON THE FOSSIL MAMMALS OF AUSTRALIA.—Part V. Genus *Nototherium*, Owen.¹

By Prof. R. OWEN, F.R.S.

THE genus of large extinct Marsupial herbivores which forms the subject of the present paper was founded on specimens transmitted (in 1842) to the author by the Surveyor-General of Australia, Sir Thomas Mitchell, C.B. They consisted of mutilated fossil mandibles and teeth. Subsequent specimens confirmed the distinction of *Nototherium* from *Diprotodon*, and more especially exemplified a singular and extreme modification of the cranium of the former genus. A detailed description is given of this part from specimens of portions of the skull in the British Museum, and from a cast and photographs of the entire cranium in the Australian Museum at Sydney, New South Wales. The descriptions of the mandible, and of the dentition in both upper and lower jaws, are taken from actual specimens in the British Museum, in the Museum of Natural History at Worcester, and in the Museum at Adelaide, S. Australia, all of which have been confided to the author for this purpose. The results of comparisons of these fossils of *Nototherium* with the answerable parts in *Diprotodon*, *Macropus*, *Phascolarctos*, and *Phascologymus* are detailed.

Characters of three species, *Nototherium Mitchelli*, *N. inerme*, and *N. Victoriae*, are defined chiefly from modifications of the mandible and mandibular molars. A table of the localities where fossils of *Nototherium* have been found, with the dates of discovery and names of the finders or donors, is appended. The paper is illustrated by subjects for nine quarto plates.

¹ Abstracted from the Proceedings of the Royal Society, No. 129, 1871.