of the smaller proportionate mass of land that would be available for their derivation, and the greater facility with which they would be denuded on mountain-tops. It is only surprising that any record whatever has been left of the presence of the waters over the steep mountain-tops, apparently out of the range of any débris excepting that derived from their own mass.

We have, however, in the occurrence of drift in North Wales at an altitude of 2300 feet, evidence of a submergence vastly greater in extent than that necessary to produce the drift-phenomena of the Severn and other valleys. Whilst we can have no certain proof of the limit to the extent or duration of the submergence, we may be allowed to conjecture that such phenomena as those developed in the drift of the Upper Severn Valley may have been but comparatively very short episodes in the history of the oscillation of level in which their deposition and subsequent denudation was included; the first during the commencement of the submergence, and the second when the present level had been nearly recovered, and the long-submerged land and its drift-beds were again appearing above the waters, presenting their surface along successive new coast-lines to the eroding action of the waves, and soon to be repeopled with terrestrial life.

FEBRUARY 3, 1864.

Charles William Villiers-Bradford, Esq., B.A., of St. Catherine's College, Cambridge, and Greatham Rectory, Petersfield, was elected a Fellow.

The following communication was read:—

On the PERMIAN ROCKS of the NORTH-WEST of ENGLAND, and their EXTENSION into SCOTLAND. By SIR RODERICK I. MURCHISON, K.C.B., D.C.L., F.R.S., F.G.S., &c., Director-General of the Geological Survey of Great Britain; and ROBERT HARKNESS, F.R.S., F.G.S., Professor of Geology, Queen's College, Cork.

INTRODUCTION. By Sir R. I. MURCHISON.

THE data which are presented to the Society in the following Memoir have for the most part been established by the researches of my associate, Professor Harkness, whose previous labours* on the same subject are well known to geologists, and who, with one exception, has prepared all the maps and coloured sections which are now exhibited.

In the following Memoir, as well as in a brief outline of the same subject communicated by us to the last Meeting of the British Association at Newcastle, we propound that which is, in truth, a new view of the aggregate of the component parts of the Permian Group in Britain. By this arrangement we place these rocks in direct

* Quart. Journ. Geol. Soc. vol. xviii. p. 206.

correlation with their equivalents in Russia and Germany—the regions in which they are most expanded, and to their arrangement in which I first called attention*. This novel feature in British classification is the absolute connexion with the Zechstein (Magnesian Limestone) or its equivalents, of great masses of superposed red sandstones, which, in the north-west of England, we propose to remove from the New Red Sandstone or Trias, to which they have hitherto been assigned, as we consider them, on the contrary, to be the natural upper limit of the palæozoic deposits. In this way, we affirm that the tripartite arrangement which I insisted on some years ago as existing in parts of Germany—of a Lower Sandstone or Rothliegende, a central limestone or Zechstein, and a connected superior sandstone—is clearly developed in the counties of Westmoreland, Cumberland, and Lancashire. As this arrangement involves a considerable change in all previous geological maps, I now present a new edition of my little general map of England and Wales, in which this new delimitation in the north-west of England is given.

It is with great satisfaction that I state, that the conviction of my colleague and self upon this point has been also arrived at by the independent researches of our friend Mr. E. W. Binney, who, more than any one of our countrymen, has vigorously and ably explored and brought into order the Permian rocks of the north-west of England, and has also followed out their relations into Dumfriesshire and the adjacent parts of Scotland†. Incredulous, in the first instance, as he has himself assured me, regarding the natural connexion in Britain between the Upper Sandstone above alluded to and those fossiliferous shales near Manchester that represent the Magnesian Limestone, he has no longer any doubt that, and entirely coincides with us in considering, the sandstones of St. Bees Head, Corby, and other places described in this Memoir, as the upper member of the Permian group.

In the following pages we indicate how essentially the Permian rocks of the north-west of England differ in lithological details from the deposits of the same age in the north-eastern parts of our country, or opposite flank of the Pennine chain—the tract which, on account of the large spread of Magnesian Limestone, and the presence of numerous fossils, has naturally been considered typical of this portion of the geological series; particularly after the masterly description of it by Professor Sedgwick, in the third volume (2nd Series) of the Geological Transactions.

At the period when Professor Sedgwick wrote, the western side of the Permian chain had been comparatively little explored; but he well described the correct mineral character and characteristic fossils of these rocks, particularly in the eastern counties, where he has since been followed by the valuable contributions of King, Howse, and Kirkby.

* See Quart. Journ. Geol. Soc. vol. i. p. 81, and 'Siluria,' 2nd edit. pp. 325 to 347.

† See the various Memoirs of Mr. Binney in Mem. Lit. and Phil. Soc., and Trans. Geol. Soc. of Manchester.

Even in the western region, to which we now invite attention, Professor Sedgwick showed the existence of equivalents of the eastern Magnesian Limestone at St. Bees Head and in Furness, though he did not propose to unite, as we do, the lower and the upper Red Sandstones in the same natural group; on the contrary, the upper sandstone (the Upper Permian or St. Bees Sandstone of our Memoir) has been left to this day in all maps as the New Red or Bunter Sandstone.

The transference of the sandstones of St. Bees and Corby to the Permian group is, we grant, not founded on any evidence of a continuation of a similar type of a fossil Fauna or Flora. We base our conclusions on the evidence afforded by clear and unmistakeable sections, which show that these upper sandstones are connected with the lower sandstone or Rothliegende through the intervention of the Magnesian Limestone or its equivalent, and that, thus united, all these strata, from the base to the summit, form a continuous series. In truth, the central or calcareous member has alone as yet proved to be really fossiliferous; certain footsteps only having been observed in the lower sandstone.

Turning to the consideration of the Continental equivalents of these rocks, let me say, that, in exploring Russia, I was led, by comparing the rocks of this age with those of Britain and Germany, to dwell upon the highly diversified or protean characters of these deposits. I observed that, in the vast regions around the large ancient kingdom of Permian, the lithological distribution was very different from that of synchronous deposits in Germany and Britain, and yet I saw that the age of the strata was clearly proved by order of superposition, and by imbedded fossils distinct from those of the Carboniferous rocks below and those of the Trias above.

My several researches in Germany having strengthened the conviction, as expressed in the second edition of 'Siluria,' and in a Memoir offered last year to this Society, it has given me great satisfaction to examine, in company with Professor Harkness, all the chief localities to which we allude, and to convince myself that these British sections fairly sustain the conclusions at which I had arrived by the survey of foreign tracts. The exploration of last summer, following upon previous examination of the fossiliferous Permian shales near Manchester, as well as my old inference that the south-western Scottish or Dumfriesshire red sandstones were of Permian age, have completely satisfied me that, notwithstanding their very striking lithological dissimilarity, the magnesian strata to the east of the Permian chain, and the red sandstones to the west of it, are truly synchronous groups. Again, in the sandstones of the east and west of England the distinction is most striking. Thus, whilst, according to Sedgwick and all his successors, including myself, the incoherent yellow sandstone of Durham is a true though poor representative of the Rothliegende of the Germans, this rock has not the remotest resemblance to the red sandstones and conglomerates which occupy the same place in the series in our own north-western tract. Even on the eastern side of the island the changeful nature of this Lower Permian Sandstone has been specially pointed out by myself. For the very same strata beneath the Mag-

nesian Limestone, which on the banks of the Wear, in Durham, are soft yellow sandstone, become on the banks of the Nid, in Yorkshire, and west of Knaresborough a pebbly brownish-red and white conglomerate, which closely resembles the Rothliegende of Germany*.

With this vast dissimilarity in the lithological development of rocks of this age in our own island, we need not wonder if we find still greater diversities prevailing when we follow these deposits into Germany and Russia. In the first of these countries the lower member of the group (Rothliegende) has been abundantly transposed by igneous eruptions, which have swollen it out and produced many modifications of original structure†. Again, in Russia, though igneous rocks are not abundant in these deposits, considerable mineral changes have been effected in them,—hot springs, sulphureous vapours, the transformation on a grand scale of cliffs of carbonate of lime into gypsum, and the diffusion of rock-salt and copper ores are abundantly displayed.

Now, although in England no clear evidences of the outburst of those eruptive rocks, or of those signs of powerful chemical action which characterize the foreign Permian rocks, have hitherto been adduced, we bring before our associates that which we consider to be a clear proof that the hæmatite or valuable kidney iron-ore of Cumberland and Lancashire was formed in the early accumulation of the Permian deposits; or, in other words, that that period commenced in the north-west of England with the formation of this ore. Whether this substance resulted from the deposit of hot springs or otherwise, we therefore regard it as one of the signs of that intense chemical agency of which the Permian rocks of the Continent offer so many proofs. As great doubts have prevailed concerning the age of this hæmatite, which occurs in the abraded cavities of the Carboniferous Limestone, we consider ourselves fortunate in being able to show its absolute connexion with the Permian breccia or conglomerate, and thus to sustain a sagacious suggestion of Professor Phillips, that such might prove to be the age of this hæmatite‡.

If it be asked whether the Trias has disappeared altogether in this north-western region, we can only say, that there are sandstones and red and green marls in the environs of Carlisle, superior to our Permian rocks, which we refer to that group; and Mr. Binney, who has also examined this area, has shown that Liassic strata occur in the flat district south of the Solway Firth.

In this Introduction I would remind my associates, that the evidences of a tripartite arrangement of the Permian group, that is, of lower and upper sandstones, and an intermediate limestone, or its fossiliferous equivalent, which we show to exist in England, enable us to correlate our British deposits of this age with the formations I have examined over extensive foreign tracts, and they demonstrate the inapplicability of the term *Dyas* to this group.

* See 'Siluria,' 2nd edit. p. 348.

† See my last Memoir on the Permian Rocks of North-eastern Bohemia, Quart. Journ. Geol. Soc. vol. xix. p. 297.

‡ See Rep. Brit. Assoc. 1858, Trans. Sect. p. 106.

The more the variable lithological development of these rocks in different countries is established, the more I venture to think that the term Permian, as taken from by far the largest region occupied by these rocks, will be approved, whenever it is applied to deposits which, however changeable in lithological arrangement and composition, are characterized, particularly in their central or calcareous portion, by those organic remains which pertain to the youngest member of the palæozoic series,—the strata of which are as clearly separated from the Carboniferous rocks beneath as from the New Red or Triassic rocks above them.

In the Memoir which follows, the different members of these Permian rocks will be described in ascending order, commencing with the Lower Red Sandstone or Rothliegende, which immediately overlies many of our coal-fields.

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 - a. Valley of the Eden, and Corby.
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§ 1. *Lower Permian, or Penrith Sandstones.*

This term, which is equivalent to that of Inferior Sandstone of Sedgwick, Lower Red Sandstone of Murchison's 'Silurian System,' and Rothliegende of the German geologists, is applied to a thick mass of rocks, usually of a light-red colour, and possessing well-marked mineral characters, as exhibited in an extensive district in Westmoreland and Cumberland, especially around the town of Penrith. The area occupied by these sandstones in Cumberland and Westmoreland has been already described*, its western and south-western margin being a line of fault corresponding nearly in extent with the Great Permian fault, as it is developed in these counties, and having nearly the same course. By means of this fault the western and south-western edges of the Lower Permian are brought into contact with the Carboniferous formation.

a. *Valley of the Eden.*—The strata composing the Lower Permian are well exhibited in the section from Great Ormside to Roman Fell,

* Quart. Journ. Geol. Soc. vol. xviii. pp. 206 *et seq.*

which may be regarded as the type-section of this series of rocks*. In this section the base of the series consists of breccias, locally called "brockrams," composed, for the most part, of unaltered fragments of Carboniferous Limestone. To these there succeeds a thick mass of red sandstones, upon which are superposed other breccias

Fig. 1.—Generalized Section of the Permian Rocks of the Eden Valley.

1. Penrith Sandstone (Lower Permian).
2. Hilton plant-beds (Middle Permian).
3. Corby or St. Bees Sandstone (Upper Permian).
4. Lower Silurian.

having red sandstones intercalated in them. The higher breccias, locally termed "rotten brockrams," are also to a considerable extent made up of limestone-fragments, but which, in every instance, are converted into dolomite. The inferior unaltered breccias are not seen in Cumberland in connexion with the Penrith sandstones; and in Westmoreland they are confined to the district west of Appleby, where alone the lowest portion of this series is seen. The succeeding sandstones, which spread themselves over the whole of the Lower Permian area, possess peculiar mineral characters. They are, almost exclusively, made up of grains of quartz, many of which retain the facets of the original quartz-crystals, reflecting solar rays therefrom. The quartz grains are of more than usual size, as compared with that of the particles of other siliceous sandstones, are angular or subangular, and give to the rocks which are composed of them the nature of a very fine-grained breccia. Owing to the abundance of oxide of iron, these sandstones have commonly a bright-red colour; but occasionally perfectly white strata are associated with the red beds, the absence of oxide of iron alone distinguishing the two. These white sandstones are largely quarried to the east and north-east of Penrith, and many new houses are built of them.

The higher breccias, "rotten brockrams," like those appertaining to the base of the series, are, in the Vale of the Eden, of local occurrence. They are well seen in the Hilton-beck, a stream descending from Roman Fell to the Eden, which traverses along the dip the greater part of the Permian rocks of Westmoreland; and they also

* *Op. cit. supra*, p. 207.

occur abundantly in the neighbourhood of Brough and Kirkby Stephen. Here the magnesian-limestone fragments frequently present themselves hollow in the interior, possessing the characters of potato-stone. Besides dolomitic limestones, these higher breccias have fragments of vein-quartz and Silurian slates entering into their composition.

The Lower Permians of the Valley of the Eden have a great thickness (2000 feet), but have hitherto afforded no fossils. Footprints have, however, been obtained from some of the beds near Penrith, and are considered to be analogous to those of Corncockle Muir in Dumfriesshire.

Although the breccias of the Penrith sandstones have, to a great extent, only a local persistence, they afford important information concerning certain superinduced structures which are, perhaps, more peculiar to the Permian formation than to any other of the groups of British sedimentary rocks. This is seen in the abundance of dolomitized or magnesian limestones which are contained in and towards the central portion of the Permian series. These dolomitized fragments of the higher breccias, there is every reason to infer, were originally deposited in the condition of simple limestones like those of the lower breccias of the same group. The magnesian breccias are not confined to the Vale of the Eden; they occur also in the course of the Shalk-beck, about two miles south of Curthwaite Station, on the Carlisle and Maryport Railway, where they form the higher member of the Penrith sandstones.

The Lower Permian sandstones of Cumberland and Westmoreland have a feature which serves to distinguish them from other and higher sandstones of the group, and which will be subsequently alluded to. They abound in hard transverse *veins* composed of quartzose sandstone, the particles of which are similar to those of the ordinary red sandstone. These veins are white in colour, and much harder than the mass of red sandstone which encloses them; every good section of the Penrith sandstones exposes them, but they are best seen in the middle portion of the series. They are strikingly exposed on the banks of the Eden, in the faces of the romantic cliffs near the Nunnery, about two miles north-west of Kirkoswald. Here they stand out from the red and white sandstones in consequence of their superior hardness, and at one spot a vein about two feet thick is a mass of perfect chert.

Veins also occur in connexion with the magnesian breccias at Hilton-beck, where they possess a somewhat different mineral nature, being composed of sand cemented together by magnesian limestone, the latter having doubtless been derived from the dolomitized fragments imbedded in the strata. The character of the veins changes as we descend Hilton-beck towards the underlying red sandstones, where ordinary white-sandstone veins make their appearance. The latter are usually widest in their upper parts, and seem to have been filled in from above.

b. *Barrowmouth, near Whitehaven.*—At Barrowmouth, near Whitehaven, on the north-east side of St. Bees Head, we have a small area of Penrith sandstones exhibited, and here also other Per-

mian rocks occur. This area, which is altogether detached from that of the Vale of the Eden and the Great Cumberland Plain, has been noticed by Professor Sedgwick* and Mr. Binney†. The Penrith sandstones here are very thin—not more than three feet on an average. Their dimensions are, however, very irregular, as they have been deposited on the eroded surface of a purple Carboniferous sandstone on which they repose (see fig. 2). In lithological character these sandstones resemble the magnesian breccias of Hiltonbeck, and, as in them, the limestone-fragments have usually the potato-stone feature. The only portion of the Penrith sandstones represented here are the highest beds.

Fig. 2.—Section at Barrowmouth, near Whitehaven.

- a. Upper Permian, or St. Bees Sandstone.
- b. Red and green marls with gypsum.
- c. Yellow magnesian limestone with fossils.
- d. Breccia of *c*, being the Upper member of the Lower Permian, passing into *c*.
- e. Coal-sandstone.

In no other localities in Cumberland or Westmoreland have we any exhibition of the Penrith sandstones, or lowest member of the Permian group. There is, on the Cumberland coast south of St. Bees, a red sandstone which has been referred to by Professor Sedgwick. This, however, is not well exposed, but it probably belongs to the highest portion of the Permian series to be subsequently alluded to.

In the district of Furness, in Lancashire, the representatives of the Lower Permian sandstones occur, but only to a slight extent, yet under circumstances of very great interest.

c. Furness area.—The Furness Railway, at Park, from about a mile and a half to two miles north of Furness Abbey, exhibits the lowest of the Permian rocks. A section opened out by the railroad-cutting is here in part through Carboniferous Limestone, which forms the lowest rock seen. Reposing upon this limestone is a mass of a peculiar character, consisting of angular fragments of limestone, partially cemented together in the higher part, but having inter-spaces between the fragments in the lower portion. This peculiar limestone-breccia is locally known as “Crab rock.”

* Geol. Trans., 2nd Series, vol. iv. p. 395.

† Mem. of Lit. and Phil. Soc. of Manchester, vol. xii. p. 51.

This "Crab rock," as seen in the section, is in some parts twenty feet thick; but its thickness is very irregular as it spreads over the eroded edges of the Carboniferous Limestone. It is seen, not only reposing unconformably upon the Carboniferous rocks, but also enclosing veins of hæmatite (see fig. 3). Another locality where this breccia or "Crab rock" appears is St. Helen's, about half a mile to the north of the Park cutting, and immediately east from the railway. Here the Carboniferous Limestones have the breccia also spread out upon their surfaces, and into some of the open joints which intersect the underlying strata the "Crab rock" has found its way. At Dalton the same relations occur. Near the church the "Crab rock," consisting of unaltered fragments of limestone cemented together by a red matrix, also covers over the Carboniferous strata. This "Crab rock" is well known to miners, who have noticed that where hæmatite occurs below it, in the Ulverstone district, the latter is always in intimate relation to the former.

Fig. 3.—Section from Park to Furness Abbey ($1\frac{1}{2}$ mile).

With reference to the position of the "Crab rock," its mineral characters lead to the conclusion that it is of like age with the lower and unaltered breccias of Burrells, west of Appleby; for it possesses none of the magnesian features appertaining to the higher breccias. Here, therefore, the lowest Permian rocks of the north-west of England are seen; and after the clear and unmistakeable natural section at Barrowmouth, under St. Bees Head, where the Lower Permian is reduced to a few feet in thickness, we have no occasion to call in the agency of great denudation in the Furness district.

In truth, it is quite manifest that along the western flank of the old slaty mountains of Cumberland we meet only with ridges or patches of Carboniferous Limestone, which, with the exception of the very partial breccias above described, are at once surrounded by the middle and higher members of the Permian group, of which hereafter.

d. *Hæmatite in the Lower Permians.*—The mode in which that valuable ore of iron, hæmatite, is found deposited in pre-existing cavities of the Carboniferous formation, and sealed up by "Crab rock," is a matter of great geological interest. Joints, fissures, and caverns were doubtless formed in the older rocks antecedent to the deposition of the Permian strata, and in these the ores of iron so widely diffused throughout the Permian rocks have, in this portion of the north-western region, assumed the characters of hæmatite.

This circumstance justifies the inference that these hæmatite ores are the result of an agency which ushered in the Permian epoch. The earlier Permian rocks of both England and Scotland are strongly impregnated with iron, their composition consisting principally of silica and an oxide of this metal.

This latter substance originated from the same source which, during the commencement of the deposition of the Penrith sandstones, filled up the fissures in the Carboniferous Limestone. This conclusion is applicable not only to the Ulverstone district, but also to that of Cleator, south-east of Whitehaven, where valuable deposits of hæmatite are also obtained from the cavities and fissures in the Carboniferous Limestone, which, at one time, was here covered over by an extension of those Permian breccias and sandstones now forming an escarpment a short distance west from Cleator Moor. This inference concerning the Permian age of the hæmatite had been arrived at by Professor Phillips, who in a communication to the British Association, of which a short abstract was published (Report of Brit. Assoc. 1858, Trans. Sects. p. 106), illustrated his opinions by maps and drawings.

There are three other small areas where the Lower Permian rocks occur in the north-west of England. They have been described by Mr. Binney. One of them is at Rougham Point, in the southern portion of the Cartmell Promontory; the second is at West House, near Burton-in-Lonsdale; and the third at Ireby, about four miles south-east of Kirkby Lonsdale. In these localities occur breccias indicative of a low position in the Penrith sandstones.

e. *Lower Permian Rocks of Scotland*.—In Scotland there are several areas where the Lower Permian sandstones occur, the details concerning which have been already published*. It is only necessary, therefore, to state that, lithologically, these Scottish Lower Permian rocks are very nearly allied to those of the Vale of the Eden, there being a breccia at the base, a middle member consisting of red sandstones identical in all respects with the sandstones of Penrith, and succeeded by higher breccias.

The difference in the rocks of the Scotch and English Lower Permians is confined to the nature of the fragments which make up the breccias. These are, in the former, for the most part fragments of the Lower Silurian rocks, against which the Permian strata of Scotland usually repose.

There is, however, one locality, namely, Dalton Hook in Dumfriesshire, where the Scottish members of the lower sandstones are precisely similar to those west of Appleby, being composed of unaltered limestone-fragments; and here the Lower Permian is in contact with the Carboniferous formation. It is not in mineral character only that the Lower Permians of the north-west of England and the south of Scotland agree; there is also a point of agreement in the footprints, the only evidence of life which these strata contain. Even as building-stones the rocks of the two countries have great

* Quart. Journ. Geol. Soc. vol. xii. pp. 254 *et seq.*

affinity; for, taking one of the areas most remote from the English border, that of the centre of the Vale of the Nith, we find that whilst the more solid and thicker red beds, out of which Drumlanrig Castle has been built, resemble the chief masses of the sandstones around Penrith, the thinner and broad flaglike portions which are exposed in the numerous quarries near Thornhill, and used for roofing-purposes in Dumfriesshire, have their exact representatives in Cumberland, in the hilly tracts N.N.E. of Penrith.

§ 2. *Middle Permian, or Magnesian Limestone Rocks.*

a. *Valley of the Eden.*—The middle member of the Permian rocks of the north-west of England—the Hilton shales, sandstones, and limestones of Westmoreland (equivalents of the Magnesian Limestone of the east of England, the Zechstein of the Germans)—has a more varied mineral character than the two other divisions of this formation. This member is well represented in Hilton-beck, overlying conformably the lower sandstones; and, as some interesting fossils occur here, the term Hilton shales, sandstones, and limestones is applied to the central portion of the Permian rocks of the north-west of England. These Hilton beds, or their equivalents, subtend and overlie the Penrith sandstone on the east, in the Vale of the Eden, and the direction in which these strata strike conforms very nearly to the course of the great Pennine fault. Southwards from Hilton-beck the Middle Permian consists of red clays, except as seen in Bela Water, where they approximate somewhat to the Hilton type; and northwards from Hilton-beck red clays are their usual components, with, in some localities, lenticular masses of gypsum. The ordinary form which they exhibit is well seen in the course of the Crowdundle-beck, at Newbiggin, in the grounds of our kind friend Mr. Crackenthorpe.

The basement-beds of the Middle Permian rocks, as seen in Hilton-beck, are finely exposed at Ash Bank, and consist of cream-coloured shaly sandstones with thin partings of grey shale, and occasionally a narrow band of impure sandy limestone which weathers brown. These beds contain a considerable number of vegetable remains, among which Mr. Etheridge has recognized the following:—*Sphenopteris Naumannii*, Gutbier, *S. dichotoma*, Althaus, *Alethopteris Goeperti*, Naum., *Ullmania selaginoides*, *U. Bronnii* (base of cones showing bracts), *Odontopteris*, sp.?, *Sphenopteris*, sp.?, and *Cardiocarpon triangulare*, Gein. Portions of coniferous wood also occur; and as the remains are usually in the form of detached leaves and bracts of cones, they seem to be the relics of autumnal vegetation*.

Of these Plants, two, *Ullmania selaginoides* and *U. Bronnii*, are common at the base of the Magnesian Limestone of Midderidge in Durham, and the other forms occur, along with *Ullmania*, in the Kupferschiefer of Germany. The fossil contents of the lower por-

* Through the kindness of the Earl of Lonsdale, the proprietor of Ash Bank, we were enabled to obtain most of the specimens of these Plants by cutting away a small portion of the escarpment in which they occur.

tion of the Hilton series indicate, therefore, an absolute identity in fossil remains with the base of the Magnesian Limestone, or Zechstein, and even in lithological nature these strata nearly approximate to the marl-slates of the county of Durham.

The plant-bearing strata of Hilton-beck are succeeded upwards by thin-bedded sandstones with impure limestones and shales, the highest member being red clays, having the ordinary aspect of the more common representative of the Middle Permian strata of the north-west of England. As the country is much covered by drift and only laid open by ravines at intervals, it is not to be expected that we should be able to follow out these few feet of plant-bearing beds upon the strike to the north or south, and, in truth, no clear evidence of their occurrence has yet been detected except by the sides of Hilton-beck.

b. *Barrowmouth, near Whitehaven.* — Beyond the Vale of the Eden and the Cumberland Plain we have the Middle Permian rocks more distinctly exhibited in the form of a true yellowish sandy magnesian limestone at Barrowmouth, under St. Bees Head, than in any other locality in the north-west of England, and in them are typical fossil Shells. These strata have been described by Professor Sedgwick* and Mr. Binney†. The latter geologist gives the section of the rocks as seen here in detail, and points out the occurrence of fossil Shells in the magnesian limestone in the state of casts. This limestone is described by Prof. Sedgwick as running S.S.E. to Ben How quarry, about a mile from Barrowmouth. We traced it still further. It is seen in Demain-gill, where it was formerly worked, and also in Chambers Bodell Wood, where it is about seven yards in thickness, and overlain conformably by red shales. This limestone changes greatly in colour, being yellow at Barrowmouth. At Preston How quarry, where it is worked for road-metal, its colour is grey, with purple spots. At Demain-gill it is still darker, and is locally known as "black limestone." Wherever it occurs, it is transgressive upon the coal-measures, as pointed out by Prof. Sedgwick, from an examination of sinkings in connexion with the Croft-pit, near Barrowmouth. This limestone, along with the overlying shales and sandstones, forms an escarpment on its line of outcrop, and this escarpment is the eastern limit of the Permian rocks near Whitehaven.

Succeeding quite conformably to the band of magnesian limestones is the highest member of the middle series of Permian rocks of St. Bees Head at Barrowmouth. This is a mass of red shales, containing fine white gypsum, which Mr. Binney estimates at 29 feet in thickness. The mineral character of this band is identical with the red shales and gypsum forming the middle portion of the Permian formation in the Valley of the Eden. At Barrowmouth, therefore, the middle member of the Permians consists of limestone with Permian Shells, and red shales with gypsum, whilst at Hilton-beck the contemporaneous strata consist of yellow and grey shales

* *Op. cit. supra*, pp. 395 and 406.

† *Mem. Lit. Phil. Soc. Manchester*, vol. xii. p. 51.

with true Permian Plants, sandstones, limestones, and red shales, passing upwards into gypsiferous red shales.

c. *Furness area*.—Another locality where the Middle Permian rocks occur is at Hole-beck, near the village of Stank, about two miles south-east of Furness Abbey. The strata here have been noticed by Prof. Sedgwick and Mr. Binney. The exposure of rocks is, however, by no means satisfactory, consisting of a small portion of an old quarry now mostly covered up with soil or by brushwood. The rock is a yellow cellular magnesian limestone, which was formerly used in the village of Stank as a building-stone. Its nature and its position with reference to the Carboniferous rocks on the north-east, and the red sandstones on the south-west, allow of very little difficulty in referring it to the magnesian representatives of the Middle Permian series.

The other areas of the north-west of England, before alluded to as containing Lower Permian sandstones, namely, West House and Ireby, do not exhibit Middle Permian strata, nor are there any clear representatives of them exposed in the Permian districts of Scotland.

§ 3. "*Hard Brockram*" of Kirkby Stephen.

Before describing the strata succeeding the Middle Permian rocks in the north-west of England, it is necessary to notice a local deposit intervening between the highest portion of the red shales and the base of the Upper Permian series. This deposit is developed only in the neighbourhood of Kirkby Stephen, especially to the south thereof, and consists of a breccia of angular fragments of Carboniferous Limestone, cemented together by a brown matrix. This is the ordinary building-stone of Kirkby Stephen, and, to distinguish it from the soft magnesian breccias, or upper members of the Penrith sandstones, it is designated "*hard brockram*." Its position and area have been previously described*. Lithologically this "*hard brockram*" is nearly allied to the inferior *unaltered* breccias at the base of the Penrith sandstones; and with reference to this, the highest of all the breccias of the north-west of England, it is interesting to notice that its *unaltered* character indicates a deposition *after* the operation of that force which dolomitized the middle members of the Permian group†.

§ 4. *Upper Permian*.

The English equivalents of this division are the St. Bees and Corby sandstones; and the foreign equivalents, the Bunter Schiefer of Germany, and the upper sandstone and conglomerate of Russia. In the north-west of England it consists of red sandstones with courses of red shales, all perfectly conformable to the underlying Permian rocks, there being a regular transition or passage into these from the Middle Permians just described. In all situations where we have examined them, whether in Westmoreland, the east of Cumber-

* Quart. Journ. Geol. Soc. vol. xviii. p. 203.

† This rock, "*hard brockram*," is mapped as Magnesian Limestone by Prof. Phillips, *Geology of Yorkshire* (1836), vol. ii., and referred to in pp. 120 *et seq.*

land, or in the north portion of St. Bees Head on the west coast, where they are largely and clearly displayed, they exhibit not only a perfect conformity to the Middle Permian strata on which they rest, but also an intimate connexion with them. Whatever may be the angle of inclination of the one is always that of the other, and nowhere is there to be seen a trace of erosion on the upper parts of the supporting strata from which a separation might be inferred, such as would be expected between rocks of palæozoic age and others of a mesozoic date. We have therefore no hesitation in expressing our conviction that these sandstones of St. Bees Head and Corby, or of the western and eastern sides of Cumberland, must be removed from the Upper New Red Sandstone or Trias, with which they have been hitherto grouped, and be viewed as the upper zone of the Permian group.

a. *Valley of the Eden, and Corby.*—The Upper Permian sandstones are only very partially represented in the higher parts of the Vale of the Eden, having been removed by denudation. They are, however, exhibited in the typical section from Great Ormside to Roman Fell, and have in Westmoreland and Cumberland as their eastern boundary, the great Pennine fault. They increase in thickness as they extend from Westmoreland into Cumberland; and they are admirably exposed in those picturesque cliffs forming the banks of the Eden to the south of Corby Castle, where their varied tints of colour, from deep red to almost pure white, and the natural caverns which have been hollowed out in them, when combined with the richest foliage, have attracted many tourists*.

In separating these Upper Permian rocks from the New Red Sandstones, we may remark that there is one characteristic lithological feature of the latter, which scarcely, if ever, appears in the former: they are hardly, if ever, spotted or “bunter.” But, in offering this remark, we by no means attach any peculiar value to it, inasmuch as the Old Red Sandstone of Perthshire, and other parts of Scotland, is, if possible, more curiously and abundantly characterized by white and whitish-green round spots than any portion of the New Red or Bunter Sandstone of England.

The great plain of Cumberland is so covered by drift that only a few spots exhibit Upper Permian rocks: one of these is Shalk-beck, a locality before referred to; and west from this point we have the Upper Permians occasionally exposed by the streams which flow northwards from Brocklebank Fells. These streams exhibit the rocks near their southern margin, which is the line of fault before alluded to as forming the south-western limit of the Lower or Penrith sandstones. This fault, on approaching the centre of Cumberland, near Dalston, takes a curved course, and then running W.S.W. enters the sea near Maryport. On assuming the W.S.W. course, the fault has, on its N.N.W. side, the Upper Permian sandstones, denudation

* Our friend Mr. P. H. Howard, of Corby Castle, has, at the request of Sir R. I. Murchison, obligingly transmitted specimens of these good and beautiful building-stones, of which the fine viaduct over the Eden at Corby is built, to the Museum of Practical Geology in Jermyn Street.

not having been sufficiently powerful in this area to remove the upper and middle members of this formation.

The extreme north-western limit where the Upper Permian sandstones are seen is Maryport, beyond which, along the southern shores of the Solway Firth, no rocks are exposed until Rockcliff is reached.

The Upper Permians, forming a trough under the drift of the Cumberland Plain, reappear on the opposite side of the Solway. They are seen at Torduff Point, five miles E.S.E. of Annan, and their extension and arrangement in the south-east of Dumfriesshire, the only part of Scotland where they have hitherto been recognized, have been already described*.

b. *St. Bees Head*.—The Upper Permian sandstones are admirably represented in the St. Bees section, and have been alluded to by Prof. Sedgwick and Mr. Binney, though referred by the first of these authors to the New Red Sandstone, and not to the uppermost palæozoic deposit as in this memoir. This upper member of the Permian formation forms the whole mass of the promontory of St. Bees Head, from Barrowmouth westwards, and here it has precisely the same intimate connexion with the middle series as in the Vale of the Eden. The upper sandstones of St. Bees are also identical in mineral character with those of East Cumberland and Westmoreland, and have the same thin red shales associated with them (see fig. 2, p. 151).

On the south face of St. Bees Head, where the successive ledges are well exposed at low water, and in the impending cliffs, the beds of strong and hard sandstone, nowhere spotted or “poikilitic,” and of brownish-red, whitish, and yellowish colours, are indeed very unlike any beds of unequivocal Trias with which we are acquainted, and have much more the aspect of coaly grits and sandstones. By referring to the section from Barrowmouth upwards it will be seen that there, as in Westmoreland, a perfect and unbroken continuation from the Middle Permian into the upper sandstones prevails, preserving precisely the same dip and strike as the fossiliferous limestones and red shales with gypsum on which these upper sandstones repose.

Along the Cumberland coast, to the south of the village of St. Bees, few indications of rock are seen; and although red sandstones do occasionally occur, they are so covered up with blown sand, and are in such small sections, that it is difficult to assign to them their exact position among the Permian rocks †.

c. *Furness area*.—When, however, we reach the north-west coast of Lancashire, the case is very different. Here, especially in the Furness district, besides the “Crab rock” (the base of the Lower Permians), and the Magnesian Limestone of Stank (a member of the Middle Permian group), we have abundant examples of the Upper

* Quart. Journ. Geol. Soc. vol. xviii. p. 214.

† Prof. Phillips refers to the Permian age a considerable part of the Red Sandstones which adjoin the Lower Palæozoic and granitic rocks about Raven-glass and Bootle. (See Geological Map of the British Isles, new edit. 1862.)

sandstones of this formation. These Upper Permian sandstones are separated, in the south and west, by a fault from the Carboniferous Limestone which contains the hæmatite ores.

Around Furness Abbey there are many fine exposures of the Upper Permian sandstones, adding greatly to the beauty of the scenery; and at Howcoat, about a mile and a half south-west of the noble ruin, these sandstones are largely worked, and are the materials which have been used in the construction of Furness Abbey.

The relation of the Upper Permian to the other members of this formation cannot be seen in Furness, the fault just alluded to bringing the higher member of this formation against the Carboniferous Limestone. The Upper Permian sandstones of the Furness area, in Lancashire, have, however, the same mineral type as those of Cumberland, and, indeed, this has been pointed out by Prof. Sedgwick, who remarks upon the identity of the latter with the sandstones of St. Bees and Furness*. In no other portion of the north-west of England do these sandstones occur save in those before referred to.

The Upper Permian sandstones have a well-marked lithological structure. They have a deeper and duller red colour than the Lower Permian sandstones, but they occasionally exhibit whitish and light-coloured layers. They have a much finer grain than the lower series; and the thin red shales, or wayboards, which are associated with them, is a feature absent from the lower or Penrith sandstones. They also frequently exhibit signs indicative of a littoral origin. But, notwithstanding these slight lithological distinctions, the mass of these lower and upper sandstones of Permian age, with their intervening deposits of limestone and gypsum, forms one unbroken and continuous series, which represents in the north-western portion of England the most complete type of the group in the British Isles, as compared with its foreign equivalents before referred to, and constituting the youngest deposits of the Palæozoic series.

§ 5. *Triassic Strata west of Carlisle.*

Before we take leave of the sandstones of the north-west of England it is necessary to refer to some strata exposed in the course of the Eden at and near Carlisle. At Etterby Seam, purple shales, with greenish-grey layers, and spots of a similar colour, are seen forming the north bank of the river. Below, on the opposite side of the river, at Eden Bank, contiguous to the North British Railway-bridge, the same strata occur, forming here a synclinal trough, the sides of which dip E.S.E. and W.N.W. at 35°. Further down the river, between Eden Bank and Grinsdale, the same strata are seen in a nearly horizontal position. A short distance from Grinsdale Church, on the opposite (north) bank of the river, there occur grey shales and impure limestones having an easterly dip, and resting conformably upon a thin series of grey gritty sandstones with rippled surfaces, the beds being about three feet in thickness. Supporting the latter are

* *Op. cit. supra*, p. 396.

grey laminated false-bedded sandstones, the lower portion of which forms a cliff, well seen near Cargs. The same light-coloured sandstones form the bed of the river to near Kirkandrews. A short distance below Kirkandrews purple and grey shales are again seen in the west bank of the river, their position being nearly horizontal; beyond which, at Beaumont, the same strata dip south at 35° , and the surfaces of the shales here are frequently marked by pseudo-morphs of bay-salt. No further traces of these rocks are seen in the Eden, nor do they occur in the district. At Rockcliff red sandstones of the Permian formation make their appearance.

The nature and arrangement of the strata seen in the sections of the Eden near Carlisle, and west of that place, are altogether different from those of the Permian rocks of the north-west of England. The highest beds here consist of purple shales with grey bands, especially in their lower portions. These purple shales greatly resemble those of the Keuper series, the grey beds upon which they rest having considerable affinity to the water-stones; and the light-coloured sandstones are probably the highest members of the Bunter. That these rocks appertain to the portion of the Trias assigned to them is still further corroborated by the fact that Liassic strata occur within a short distance southwards, as shown by Mr. Binney*.

The occurrence of Triassic and Liassic strata in this part of Cumberland results probably from faults throwing down these and the underlying formations. In no portion of Cumberland, however, have we any evidence of the mode in which the lower members of the Mesozoic group are associated with the upper portion of the Palæozoic division.

§ 6. *Dolomitization.*

Reference has already been made to the unaltered character of the lower sandstones. Their nature shows that the dolomitizing influence had not begun to act when they were being deposited. The period when this agency commenced, and that when it ceased, can, so far as the Permian rocks of the north-west of England are concerned, be very nearly determined. Dr. Blyth, of Queen's College, Cork, has kindly furnished us with the results of his analyses of different rocks from various portions of the Permian formation of Cumberland and Westmoreland.

As regards the red sandstones of the Penrith series, a specimen of these from the Beacon quarry, about a mile east of Penrith, consisted almost exclusively of quartz-granules; the cementing matrix of these granules being silicates of lime, iron, and magnesia, the two former being in greater proportions than the latter. The red colour of this sandstone is owing to a considerable amount of oxide of iron incrusting the silica-granules, which can be dissolved off, leaving the granules quite white. The *white* sandstones, occasionally associated with the lower sandstones in the same locality, consist also of quartz-granules cemented together by the same substances; but here the silicates of lime and magnesia are in excess, while the silicate of

* Quart. Journ. Geol. Soc. vol. xv. p. 549.

iron is in smaller proportions; and in this *white sandstone* there is no incrusting oxide of iron. The presence of oxide of iron as an *incrusting* material at this early period of the Permian formation is a proof of the abundance of the substance, which now occurs as veins of hæmatite filling up the fissures in the Carboniferous rocks, during the commencement of the Permian epoch.

The presence of silicate of magnesia as a cementing material in the quartz-granules in the Penrith sandstones indicates the early occurrence of magnesia, a substance more abundant in the Permian than in any other group of rocks.

Evidence of the occurrence of abundance of magnesia during the Permian epoch becomes more prominent in the upper beds of the Penrith sandstones, a portion of dolomitized Carboniferous Limestone from the magnesian breccias of Hilton-beck yielding Dr. Blyth the following results:—

CaO, CO ₂	65·0
MgO, CO ₂	29·4
Carbonate of iron and silica ..	5·6
	<hr/> 100·0

Regarding this rock Dr. Blyth observes that, by deducting the carbonate of iron and silica, and calculating the mixed carbonates of lime and magnesia, we have

CaO, CO ₂	68·8
MgO, CO ₂	31·2
	<hr/> 100·0

Rammelsberg has given three proportions, to which the composition of bitter spar and dolomite approximates more or less (Bischof, ii. p. 47), namely:—

First,	1 CaO, CO ₂	54·18
	1 MgO, CO ₂	45·82
		<hr/> 100·00
Second,	3 CaO, CO ₂	63·95
	2 MgO, CO ₂	36·05
		<hr/> 100·00
Third,	2 CaO, CO ₂	70·28
	1 MgO, CO ₂	29·72
		<hr/> 100·00

The dolomite of the magnesian breccia of Hilton-beck agrees nearly with the third approximate formula which Rammelsberg gives for dolomite = 2CaO, CO₂ + MgO, CO₂. Of this composition are the dolomites from Kolozomek, of Glücksbrunn *, and a variety from the Tillerthal. The dolomitizing here has been complete.

Reference has already been made to the hard veins of light-coloured sandstone which intersect the lower sandstones. Their

* For a description of the dolomites of Glücksbrunn, and their position, see 'Siluria,' 2nd edit. p. 340.

cementing substance generally consists of the same materials as those which unite the quartz-granules of the rocks in which they occur; but when they appear among the magnesian breccias, they have, however, a different cementing matrix. A portion of one of these from the higher part of the Penrith sandstones of Hilton-beck, as determined by Dr. Blyth, afforded the following results:—

CaO, CO ₂	16·00
MgO, CO ₂	1·75
Silica	76·20
Carbonate of iron and moisture	6·05
	<hr/> 100·00

Rejecting the sand and iron from this specimen, and calculating the percentage of lime and magnesia, gives the following result:—

CaO, CO ₂	91·36
MgO, CO ₂	8·64
	<hr/> 100·00

In this case the cementing matrix, although of dolomite, has had the dolomitizing process much less advanced than is the case with the fragments making up the magnesian breccias.

In the Hilton group a specimen of the impure limestones associated with the plant-beds yielded Dr. Blyth the following constituents:—

CaO, CO ₂	24·4
MgO, CO ₂	1·7
Si O ₂	70·0
Oxide of iron	3·9
	<hr/> 100·0

The dolomitized limestone, the cementing matrix of the sands in this stratum, had the following composition:—

CaO, CO ₂	93·1
MgO, CO ₂	6·9
	<hr/> 100·0

In this specimen the cementing matrix has a great affinity to that of the siliceous vein just described.

Immediately beneath the red shales of the Hilton section a thin mass of grey limestone occurs, containing drusy cavities, and much resembling in aspect the compact limestone of the county of Durham. This limestone approaches very nearly to a true dolomite.

No calcareous rocks are seen in the Hilton section above this limestone, but in the Kirkby Stephen section the “hard brockram” has a higher position, appearing above the red shales. The unaltered condition of the limestone-fragments in this “hard brockram” indicates the termination of the action of that force which gave rise to dolomites, anterior to the period of deposition of these “hard brockrams,” and shows that the action of the dolomitizing agent was confined to the middle portion of the Permian epoch.

The Upper Permian rocks—the St. Bees and Corby sandstones—

afford further proof that the dolomitizing influence had ceased to operate anterior to their deposition. Dr. Blyth finds that these rocks are composed of small rounded quartz-granules, with a cementing matrix of silicates of lime and iron, very little magnesia being present. Their deep-red colour, owing to oxide of iron as in the lower sandstones, is merely *incrusting*, and can be dissolved off, leaving the granules perfectly colourless.

The mode in which the magnesian breccias and limestones occur in the north-west of England leads to the conclusion that the dolomitizing agent must have acted from above. Had this cause exercised its influence from below, it would have operated powerfully on the lower breccias; and yet these, as seen in the north-west of England, are perfectly unchanged, while the higher breccias always exhibit the magnesian-limestone character. These latter have also been subjected to a force which dissolved a portion of carbonate of lime from the fragments, converting them into potato-stones; the dissolved portion, combining with carbonate of magnesia, furnished the materials out of which the regular stratified dolomites were formed, or, becoming mixed with other mineral matter, constituted its cementing matrix; in which condition we have it, in the plant-beds of Hilton, giving rise to dolomitic sandstones.

Concerning the dolomitizing cause, this has been frequently discussed both by chemists and geologists. One circumstance, namely, the occurrence of gypsum, either in beds associated with magnesian limestone or in deposits appertaining to the period when this kind of mineral matter was very abundant, seems to connect gypsum with dolomites, since at St. Bees Head the former occurs in red shales immediately overlying magnesian limestone, and in several portions of the Vale of the Eden gypsum and red shales are the exclusive representatives of the Middle Permian series. This association supports, to some extent, the conclusion that the magnesia of the dolomites originally existed as a sulphate of this earth, from which was derived the sulphuric acid combined with the lime in gypsum.

§ 8. *Conclusion.*

The Permian rocks of the county of Durham have hitherto been regarded as the type of this formation in England. In this county, however, excepting the middle member, the strata appertaining to this portion of the Palæozoic period are very imperfectly represented. Of this group the base is almost absent, the Penrith sandstones occurring only to a very slight extent as soft sandstones, supporting the base of the magnesian limestones—the equivalents of the Hilton series—and in many localities these sandstones disappear altogether. In the county of Durham the portions of the Permian strata which occur are transgressive on the coal-measures, and are spread out upon the eroded surfaces of the latter rocks. At Tynemouth, beneath the “brecciated limestone” forming the upper portion of the cliffs, this eroded surface is seen in the light-coloured sandstone supporting the Permian breccia-beds. This light-coloured sandstone is said to pass downwards into another sandstone with

a purple tint, and the latter rests conformably upon shale which equally conforms to the seam of coal seen at Cullercoats and known as the Hebburn seam. In the red sandstones immediately above, and conformable to the Hebburn coal, Plants occur, consisting of species common in the Coal-measures. They have no relation to the true Permian Plants such as are obtained from the marl-slate of Durham and its equivalent—the Hilton leaf-beds of Westmoreland; and the evidence, both as regards stratigraphical arrangement and fossils, removes the sandstones north of Tynemouth from the Lower Permian or yellow sandstones of the Wear, and places them in the Carboniferous formation.

With regard to the nature of the Plants of the true Permian strata, they have a widely different *facies* from that which the carboniferous Plants present. No traces of either *Lepidodendron* or *Sigillaria*—so abundant in the Coal-measures—have been hitherto met with in the Permian rocks; and with reference to seeds, while *Trigonocarpon*, a fruit appertaining to the *berry-bearing* Coniferæ, occurs in the Coal-measures, it is absent from the Permian group, the seeds occurring in the latter being the products of *cone-bearing* pines which make their appearance *for the first time* in the Permian formation.

Of these Coniferæ of the Permian strata, two forms of *Ullmania*, a genus unknown in the Carboniferous formation, are abundant, the cones of which seem to have been of small size; and as regards Ferns, these also in the Permian rocks are altogether distinct from such as occur in the Carboniferous group. The fossil plants are, therefore, characteristic of, and peculiar to, the Permian series; they also indicate different climatal conditions; and, if we may judge from the relative size of the cones of the Gymnosperms, we should infer that a somewhat lower temperature obtained during the Permian than during the Carboniferous epoch.

Although there is no great band of Magnesian Limestone like that of Durham and Yorkshire to mark the central division of the Permian rocks of the north-west of England, we hold that the series we have described in the Valley of the Eden is much fuller and thicker than its equivalent in the north-eastern counties. In the north-east of England, not only is the Lower Permian or Rothliegende most slenderly and imperfectly represented, but the highest member of the group is entirely wanting. On the other hand, the splendid development of the Magnesian Limestone, in its range from the coast of Durham through Yorkshire and into Nottinghamshire, is so much superior in volume to its feeble equivalent in the region under consideration, that some geologists may be induced to view the Upper Sandstones of St. Bees and Corby as synchronous with the Upper Magnesian Limestones and red marls of the Yorkshire series. In contrasting the siliceous character of the Permian group of the north-west of England with its eminently calcareous development in Durham and Yorkshire, it is to be borne in mind that even the latter band, when it trends southwards into Nottinghamshire, becomes so sandy a rock, that the freestones of Mansfield, of both red and whitish colours, might, from their aspect, be mistaken for sandstones. It was the least calcareous

of these masses which was recommended by Sir Henry De la Beche as the building-stone of the Houses of Parliament; and had his advice not been departed from, by resorting to the Anstone quarries in Yorkshire, the beautiful freestone of Mansfield would, we are persuaded, have been through ages unaffected even in our London atmosphere. The sandy varieties of the Magnesian Limestones of Nottinghamshire were long ago well described by Prof. Sedgwick, and recently their analyses were given in the Memoirs of the Geological Survey, in Mr. Aveline's description of the Quarter-sheets N.E. 71 and S.E. 82.

We may, indeed, adopt the view of synchronizing the red marls and sand-beds which overlie the Magnesian Limestone of Nottinghamshire with the St. Bees and Corby Sandstones of the north-west; and in this way, though the thickness of the Nottinghamshire band is small, it has been clearly represented in the Geological Maps of the north and south of Mansfield by Mr. Aveline, and even there we have thus a tripartite arrangement of the group. In Ireland, also, it is probable that the Upper Permian is represented by the red sandstones which at Rhone Hill, near Duncannon, co. Tyrone, afford *Palæoniscus catopterus* (Ag.); for these beds have an intimate relation in mineral nature to the St. Bees and Corby Sandstones.

However this may be, we simply call attention to the fact that on the western side of the axis of the north of England, or Pennine Chain, the Permian Group, from its base to its summit, consists of a *triplex* conformable series similar to that which was long ago described by one of us as prevailing over wide tracts of the Continent of Europe.

The establishment of a vast range of Permian rocks in the north-west of England is connected with the probability that productive Carboniferous deposits will at a future day be attained by sinking through some of the superjacent Red Sandstones. Near Barrow-mouth, at St. Bees Head, coal has been indeed worked for many years under the Magnesian Limestone, the Lower Permian having there become very thin; and we see no reason why coal may not be found, though at greater depths, under the Red Sandstone north-west of the village of St. Bees. Again, immediately south of Maryport, where the productive coal-measures dip northwards, they are flanked on the north by the Upper Permian, from which they are separated by the powerful fault before alluded to. Now, if the Lower Permian should have become thin here, as it has done in the environs of Whitehaven, coal may very well be won by shafts sunk through the Upper Permian Sandstones. Lastly, the small but highly productive coal-field of Cannoby, lying on the northern side of the great Pennine fault in its extension into Scotland, is seen to have its strata dipping southward, or directly towards the Corby Sandstones or Upper Permian. We have therefore little doubt that, at a depth which we will not pretend to estimate, the coal-beds of Cannoby, which have been abruptly broken off by the great downcast fault extending under the Red Permian Rocks, and under the Solway Frith, may in this way be viewed as the north-eastern limb of the West Cumberland or Whitehaven coal-field.