THE GEOLOGY OF NORTH-WEST CUMBERLAND.

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I.—THE CARBONIFEROUS, PERMIAN-TRIASSIC, AND LIASSIC ROCKS.

It is obvious, on glancing at a geological map, that the Carboniferous rocks of this district encircle the Silurian strata of the Lake Country, and are themselves encircled by the Permian-Triassic beds. They consist of beds of limestone, sandstone, shale, and coal, thick limestones being found only among the lowermost beds of the series, in the high ground just outside the mountain country. There the fells rise to a height of 1,000 to 1,200 feet or more, while as we approach the Solway the average height of the ground gradually diminishes. On the day of our ascent of Chalk Beck we shall begin our walk on the St. Bees Sandstone at a height of about 200 feet above the sea, and arrive before the end of the day among the Carboniferous Limestones and other beds of Warnell Fell at a height of between 900 and 1,000 feet.

Chalk (Shalk, Shawk, or Choke) Beck affords an admirable and almost continuous series of sections in the Carboniferous strata intermediate between the lowest beds, in which thick limestones predominate, and the Coal-measures or uppermost division. It will be found that, though there is limestone of Carboniferous age near the old lime-kiln, just above the spot at which the Carboniferous-Permian-Triassic junction is seen, no more bands of limestone are visible nearer than a spot just below the house called Ninegills, about three miles higher up the stream, the measures seen consisting of sandstones and shales. These beds vary in the direction of their dip from about 10° north of east to 10° east of north, the amount being often high. Their colour varies, but is frequently reddish or purple-grey. At Ninegills a fault ranges across the Beck in a north-west and south-east direction, having a downthrow to the south-west, so that while from the Permian-Triassic boundary

to Ninegills we have been gradually traversing lower and lower beds, we are, after crossing this fault, on beds geologically higher than those a few yards down the stream. These higher beds above Ninegills are considerably redder in tint than those just below the house, though not more so than the measures a mile or more nearer the Permian-Triassic junction. On getting on to the high common, a little beyond the head of Chalk Beck, indications of many old coal-workings may be seen. Hutchinson (Vol. ii, p. 390) quotes some remarks by a resident at Caldbeck on the Warnell Fell coal, from which it appears that this coal was worked in a pit there, where it was found at a depth of $55\frac{1}{2}$ fathoms and was 16 inches thick. The following is the section given, reduced to feet:—

	Thickness.	Depth.
Clay	60ft.	60ft.
Day freestone metal	24ft.	84ft.
Day freestone	84ft.	168ft.
Day freestone metal	84ft.	252ft.
Day limestone	9ft.	261ft.
Main limestone metal	33ft.	294ft.
Main limestone... ..	12ft.	306ft.
Coal freestone	18ft.	324ft.
Grey-beds and metal	9ft.	333ft.
Coal	1ft. 4in.	

The term “metal” means shale. In three boreholes on the Warnell Estate made in 1888, one 29 feet 6 inches deep, another 85 feet, and a third 105 feet, neither coal nor limestone seems to have been met with. At Denton Holme Colliery, Sebergham (Engine Pit) the section was:—

	Ft.	In.
Soil, clay, and gravel ...	23	6
Sandstone and shale...	88	0
Hard, grey limestone...	13	4
Sandstone and shale ...	17	6—142·4
Coal	1	8

These sections are given both to illustrate the average thicknesses of the coals which have been worked on this geological

horizon hereabouts and the nature of the beds associated with them. But one thin limestone band occurs in each of the two collieries.

The lowest Carboniferous beds in the neighbourhood of Caldbeck, those in which thick limestones predominate, are so much dislocated by faults and obscured by drift that any given bed of limestone is with difficulty traced for more than a mile, if so far. For example, if on arriving at the common a little beyond the head of Chalk Beck we proceed in a south-easterly direction, in order to inspect the thick limestones about Parkhead before descending to the village of Caldbeck, we find below the Parkhead Limestone two other massive beds of that rock, which make bold escarpments on the fine hillside between Parkhead and the stream called the Caldbeck. But to get to the village of Caldbeck we must go from Parkhead, not in a southerly, but a south-westerly direction, for a distance of about a mile.

However, instead of crossing, as might be expected, the thick limestones below that of Parkhead, we find no signs whatever of their existence, such beds as are visible being sandstone and shale, while here and there old coal-work-

ings, such as we saw on the top of Warnell Fell, appear. In short, a fault, ranging about N.N.W. and S.S.E., with a downthrow to the west, crosses the hillside, and throwing down the limestones some distance, gives us at the surface in their stead, measures such as those which overlie the limestones on the top of Warnell Fell. The sudden disappearance of the limestone terraces on the hillside is well shown from the road between Caldbeck and Hesket Newmarket, which commands a fine view of the bold hillside north of the stream.

The most common fossils in the limestones are encrinites ; but in some a species of *Productus* is very abundant.

The experience gained in Chalk Beck, to the effect that limestone beds are few and thin as we ascend in the series, is one that would be confirmed should any other route be taken from the low ground near the Solway to the Limestone Fells.

I have already stated that though we started from the Permian-Triassic junction at Chalk Beck, the uppermost Carboniferous rocks there visible are on a lower geological horizon than the measures of the Coalfield of the coast between Whitehaven and Maryport, which forms a narrow belt of country south of the Permian-Triassic area about Dearham, Blennerhasset, and Mealsgate. The north-easterly prolongation of this coalfield, from Dearham to Mealsgate and Bolton-Low-Houses, is due to the existence of a line of fault, ranging in a north-easterly and south-westerly direction, a little northward of Plumbland, Torpenhow, and Boltongate, which has a downthrow to the north-west. The effect of this fault may be thus pointed out. We have seen that in Chalk Beck there is a vast thickness of beds of sandstone and shale, with scarcely any limestone, between the thick limestones of the fells and the Permian-Triassic boundary. Now if we travel five or six miles westward of the upper part of Chalk Beck we come to Catlands Hill, where thick limestones predominate. But instead of a series of rocks such as we found in Chalk Beck, directly northward of Catlands Hill we have collieries in which are, or were, worked the thick coal-seams of the Coal-measures proper, the intermediate series existing in the Caldew and in Chalk Beck ceasing to appear at the surface at all. Considering the shortness of the distance between Chalk Beck and Catlands, and the great thickness of this intermediate series, it is obvious that

the existence of a line of fault of great magnitude is the only agency which will account for the state of things observed. (See Fig. 3.)

FIG. 3.—Diagrammatic Section from Catlands Hill to Bolton-Low-Houses.

I need say nothing about the Coal-measures of the Whitehaven and Maryport Coalfield as regards the thicknesses of the coals worked there, or the average distances between those of most repute; but there is a certain bed which we shall see between Whitehaven and St. Bees which merits some little attention, viz., the rock known as the Whitehaven Sandstone. This is of a generally purple-grey colour, and is seen to rest unconformably on Coal-measures with sandstones of a brown or buff tint. This unconformity, together with the colour of the Whitehaven Sandstone, caused it to be supposed at one time that its affinities were rather Permian-Triassic than Carboniferous, and it is accordingly classed with the former by some of the earlier writers on the geology of this part of Cumberland. Its position, however, in the Cumberland Coalfield is precisely analogous to that of the Red Rock of Rotherham in the Yorkshire Coalfield. It is an Upper Carboniferous rock, being at the same time unconformable to the Carboniferous rocks, on which it rests, and to the Permian-Triassic series above. It is known to exist in many places east and north-east of Whitehaven, and we shall obtain a glimpse of

it at Rosegill, between Bullgill and Dearham Railway-Stations, where there are quarries in it.

But though at Whitehaven it is distinguished among the Carboniferous rocks by its redder tint, the Whitehaven Sandstone is by no means remarkable among the Carboniferous strata of Cumberland generally on account of its colour. Beds of pinkish or purple-grey tints are more or less common at every stage of the Carboniferous Period, and in every part of Cumberland where Carboniferous rocks are seen. They abound in Chalk Beck, the Caldew, in the Waver near Bolton-Low-Houses (on the Coal-measures proper), and northward in the Esk, the Line, the Hetherburn, and other streams. One consequence of the erroneous notion that beds of these colours were necessarily on the Whitehaven Sandstone horizon, and were of Permian-Triassic affinities, is shown in all old geological maps of this district. There we find the Permian-Triassic boundary ranging due east from Aspatia towards Caldbeck, so as to include as New Red Sandstone the whole of the Carboniferous Rocks of Chalk Beck, the line being drawn a little northward of Caldbeck, so as to exclude the old coal-workings of Warnell Fell. Thus, by this rash reliance on colour, unsupported by other evidence, beds which, as we have just seen, are of Coal-measure age, were classed with others of earlier date as alike Permian-Triassic.

Alike at St. Bees Head, however, in Chalk Beck, and at every other place where the Carboniferous junction with the overlying rocks is visible, we shall find that the characteristic tint of the Permian-Triassic stone is brick-red, and that of the Carboniferous rocks, where they are brightly coloured, pinkish or purple-grey. In many cases fragments of Carboniferous Sandstone may be seen lying about here and there which have precisely the appearance of fragments of St. Bees Sandstone; but on breaking the fragments with a hammer the purple-grey colour becomes at once manifest. So invariably has this change of hue been noticed to accompany an unconformable junction, that the geologist can now feel a confidence in this colour-test, where other evidence is unavailable, that would otherwise be wholly unjustifiable.

In the Kirklington district we shall also have opportunities of seeing something of the Carboniferous rocks of pre-Coal-measure

age; but as the sections seen there have no special interest as Carboniferous sections, it seems best to defer any notice of them till those localities are described in connection with the Permian-Triassic rocks.

II.—THE PERMIAN-TRIASSIC AND LIASSIC ROCKS.

In this district, west of the Caldew, we see nothing of the great Penrith Sandstone, the lowest of these beds; for only about Rose Castle does it probably cross the Caldew, and there it probably covers but a few acres west of the alluvium of that stream. North and east of Carlisle it nowhere is visible, as two faults, which abut against each other close to the Petterill, a few yards above Newbiggin Bridge, and have, both of them, a downthrow to the north or north-west, throw down the great (upper) Sandstone of St. Bees against the great (lower) Penrith Sandstone. North of these faults, the more westerly of which ranges from Newbiggin Bridge to the Caldew, a little northward of Rose Castle, while the other's course is from Newbiggin Bridge to Brackenbank on the Eden, the Penrith Sandstone is nowhere seen in Cumberland. We shall see, during the Kirklington Excursion, in Carwinley Burn and the Hetherburn, that, putting aside a very thin breccia, the St. Bees Sandstone directly overlies the Carboniferous rocks in that quarter. Nothing is seen of the Penrith Sandstone in the Esk or Liddel, the Kirtle Water or the Annan Water, on the Scottish side of the Border; but a massive rock much resembling it, and containing thick beds of breccia, may be seen east of the Nith, between the town of Dumfries and the castle of Caerlaverock.

Of beds below the St. Bees Sandstone, therefore, we shall see but little, and that little almost wholly during our Excursion to St. Bees Head. The section at Barrowmouth, according to Sir R. Murchison and Prof. Harkness, consists of —

	Ft.
St. Bees Sandstone 	... 1,000 ?
Red Marls, with gypsum interstratified	... 30
Magnesian Limestone, thickening inland	... 11
Breccia 	... 3

The breccia rests upon Carboniferous rock. Thus the great mass of Penrith Sandstone, which where the Magnesian Lime-

stone is seen in the Eden Valley district underlies it, does not here exist.

Between St. Bees Head and Maryport marine denudation has swept away the St. Bees Sandstone. But it reappears in quarries close to Maryport, and in others between Aspatria and West Newton. We shall pass a quarry close to the railway west of Brayton Station, and shall be able to inspect a series of good sections of the Sandstone in Chalk Beck, between East Curthwaite and the road from Near Welton to Rosley Rigg. We shall also see it in the Kirklington district and the Eden Valley.

The difference in appearance between the St. Bees and Penrith Sandstones is very marked. The Penrith is of a lighter and brighter red, and is false-bedded on a very large scale. The St. Bees Sandstone is finer in grain and of a deeper red, and is seldom false-bedded. Occasionally bands of lighter coloured stone, buff or whitish, are found in it. Towards its base it becomes very thin-bedded and flaky, resembling what would in some parts of the country be called stone-bind, or sandy shale. This will be seen in Chalk Beck, and near the junction with Carboniferous rocks at Hethersgill. The unconformity at Hethersgill may be seen in the stream where it bounds the field south-east of the Grainhead farm-buildings. It is a little above the bridge.

On the Line near Brackenhill Tower a fault, ranging nearly north and south, brings in the Carboniferous rocks on its eastern side, against the St. Bees Sandstone. Above this point Carboniferous Beds only are seen. The scenery of the Line between Cliff Bridge and Shank Bridge is extremely picturesque, as well as highly interesting geologically. I trust we may be able to walk along the bank of the river from the Brackenhill Fault as far as Cliff Bridge. In Carwinley Burn the St. Bees Sandstone is seen to be extremely thin. On the other side of the Border it must attain a much greater thickness between the Sark and the Annan Water.

Thus, northward of the two faults, between Brackenbank on the Eden and Rose Castle on the Caldew, the St. Bees Sandstone is the oldest of the Permian-Triassic rocks of Cumberland. It is also evident from its southerly dip about Annan, and its northerly dip about Chalk Beck and Aspatria, that it forms the outer formation of a geological basin—which I have elsewhere

called the Carlisle Basin—the western margin of which is below the Solway. We have now to notice the various formations in the Carlisle Basin which overlie the St. Bees Sandstone.

Above it, east of the Lias outlier, is a very soft, usually bright red, false-bedded sandstone, which I have called the Kirklington Sandstone; but west of the Lias, borings have revealed the fact that resting directly above the St. Bees Sandstone are about 700 feet of gypseous shales. There is no evidence sufficient to settle conclusively which is the older formation, but it seems to me that what is available gives a slight presumption in favour of the greater age of the Gypseous Shales. I will, therefore, deal with them first.

A boring made about fifteen years ago, near Abbey Town, disclosed the fact that below nearly 200 feet of beds belonging to the Glacial Drift there were about 700 feet of Gypseous Shales resting upon St. Bees Sandstone. And another boring, made some time before that, near the west end of Bowness, at high water mark, had shown the presence there of 367 feet of Gypseous Shales below 41 feet of Glacial Drift and above St. Bees Sandstone. Eastward of these two places the only evidence of the existence of these Gypseous Shales is in the record of an old boring near Great Orton. There, below 18 feet of Drift, and 210 feet of rock evidently Liassic, was “red stone or clay, sometimes mixed with veins of white,” to a depth of 360 feet, or 142 feet of these beds at least, the boring having been ended in them. As the gypsum at Abbey Town was in thin laminæ, this description of the undermost rock of the Orton boring suits the Gypseous Shales very well. But the only evidence of the existence of this formation is that of the three borings I have named. Nothing that can anywhere be seen eastward of Orton would suggest the remark “These beds are evidently the Gypseous Shales.”

I now come to the Kirklington Sandstone. From my remarks on the Gypseous Shales it is evident that we have no evidence whatever that they lie unconformably on the St. Bees Sandstone. As it seems to me that there is evidence that the Kirklington Sandstone does do so, I have treated the latter as the newer formation. In appearance this sandstone is very unlike that of St. Bees. Except in its upper beds, as shown in Skew

Bank, north of Grinsdale, and reported in certain borings at or near Carlisle, its colour is of a bright, almost scarlet red, sometimes mixed, more or less, with white. But the Skew Bank Sandstone is almost quite white, and the borings alluded to mention much stone of that colour. It may be seen near Carlisle, at Holmhead, and Cummersdale on the Caldew, at Rickerby, and near Holmgate, on the Eden, and in the Hetherburn, between Hether Bank Bridge and Cliff Bridge. In the Line there is an excellent section at Cliff Bridge, and thence as far as Shield Green, the last-named place being between Kirklington Hall and the Muckle Linn. Below Cliff Bridge it is seen in the Line at Westlinton and at Metal Bridge, just below the junction of the Line and Esk, while in a boring at Linehow, or Justice Town, 170 feet of Kirklington Sandstone were found, resting on that of St. Bees. It also forms the cliff at Rockcliff on the lower Eden. Higher up the Esk it is seen beneath Longtown Bridge, and at various spots in the river-bank opposite Netherby; and it is well displayed in the sides of the beautiful gorge, in which Carwinley Burn flows, between Carwinley Mill and its outfall into the Esk.

The Kirklington Sandstone, besides being of a much brighter colour than the St. Bees, is a very false-bedded rock, and so uniformly soft that it is scarcely ever quarried. Indeed, I can only remember one place where it is hewn for building purposes, and that is on the Line between Shield Green and Kirklington Hall, where a harder band appears to be interbedded with it. In this harder band, which may be 30 feet or more in thickness, are two quarries, one in the northern corner of Hirst Wood, the other at Stag Ford, about 500 yards away. In the neighbouring Hetherburn no quarries are seen between Cliff Bridge and Hether Bank Bridge, where the Kirklington Sandstone is at the surface, while they abound above Hether Bank Bridge, where the St. Bees Sandstone appears.

Two outliers of Kirklington Sandstone exist. One rests on Carboniferous rocks opposite Canobie Church, on the Scottish side of the Border; the second is on the Cambeck, near Walton, and lies upon St. Bees Sandstone.

We may now consider what evidence there is pointing to an unconformity between the Kirklington and St. Bees Sandstones. Six or seven miles south-east of Carlisle Mr. Goodchild estimates

the thickness of the St. Bees Sandstone at from 1,500 to 2,000 feet; and its thickness at and around Brampton can hardly be less. It is also very thick between the Sark and the Annan Water, on the northern side of the Solway, and between Maryport and the Caldew. But at Hethersgill there can scarcely be more than 800 feet of St. Bees Sandstone, and in Carwinley Burn, where its full thickness is also seen, there are only about 250 feet of it. Both at Hethersgill and in Carwinley Burn there is an almost continuous series of sections, and there are no signs of faults. Thus not only are the Gypseous Shales (found to be at least 142 feet thick at Great Orton) wanting towards the north-eastern end of the Basin, but a very large proportion of the St. Bees Sandstone has also disappeared in that quarter, though both about Brampton on the one side, and between the Sark and Annan Water on the other, it is extremely thick. These considerations seem to me to point to a very decided unconformity between the Sandstones of Kirklington and St. Bees.

I have preferred the name Kirklington Sandstone to any other for the rock we have just been considering, because in that quarter only are its relations with the beds both above and below it observable. In addition, the river Line, though from Cliff Bridge upwards one of the most picturesque and geologically interesting of Cumberland streams, is singularly little known. Even the late Prof. Harkness, whose knowledge of Cumberland geological sections was exceedingly extensive, had never visited the Line before the year 1876, and was then much surprised to find out how much there was worth seeing in a quarter he had never previously thought of visiting.

The Stanwix Marls, so-called because they appear at the base of the river-cliff of the Eden, at Etterby Scaur, in that parish, may be seen lower down the river between the North British Railway Bridge and Grinsdale, and again about Beaumont, on the left bank of the stream. Their junction with the underlying Kirklington Sandstone is visible close to Westlinton Bridge, on the eastern side, and also in two places close to Cliff Bridge; and the Marls themselves may be seen here and there in the little streams which unite and fall into the Line between Low Alstonby and Westlinton, nearly as far eastward as Stony-sonerigg.

There is no evidence to determine how far they may extend south of the Eden at Beaumont; but they seem to be very thin at Carlisle. They evidently rest unconformably on the Kirk-linton Sandstone. North of the Eden at Carlisle I have seen them as far to the east as the high bank in Rickerby Park, near the road between Carlisle and Low Crosby, and about as far away as the first milestone. South of the Eden at Carlisle I once saw a few feet of shales in an excavation at the foot of Gaol Brow; but elsewhere I have seen nothing but more or less

FIG. 4.—Section to illustrate the necessary thickness of the Stanwix Marls in Caldewgate, W. of Carlisle, indicated by their absence beneath the Alluvial Flats.

decomposed material resembling the Marls, and never the rock itself in place. In the Carlisle Water-Works Extension on Stony Holme in 1886 (for sections of which I am indebted to the kindness of Mr. R. S. Ferguson) red sandstone was found below river-deposits. The Marls were not found in the deep wells of Messrs. Carr, Caldewgate, and Messrs. Dixon, West Tower Street, and three new railway-bridges over the Caldew, made twelve or thirteen years ago, the lowest of which is close to the junction of the North British and Caledonian Railways, are all based on the underlying sandstone, the Stanwix Marls not having been seen. West of the Caldew there is little evidence; but Mr. E. W. Binney records that at the pumping-engine for the canal by Edenside, which was close to the North British Railway-Bridge, and at a spot where the Marls form the base of the river-cliff, there was a section "which distinctly showed the Marls at the top passing down into the red sandstone below." Mr. R. B. Brockbank also informed me that he used at one time to bathe in a long pool just below this spot. The sides of this pool consisted

of ledges of rock ranging parallel with the line of the cliff, and which, being from one foot six inches to two feet in depth, could hardly have been made by anything but the underlying sandstone.

The whole of the available evidence, therefore, points towards these conclusions :—

That at, and more than a mile west of Carlisle, the Stanwix Marls are extremely thin, their out-crop, below the Drift, being probably a nearly east and west line, either through or a little north of Newtown. Therefore it is highly improbable that they underlie the Lias, except towards its north-eastern boundary. (See Fig. 4.)

The Stanwix Marls at Carlisle appear to be unaffected by any considerable fault, none being known but that which brings them in on the eastern side of Skewbank. If prolonged southward this one points towards a spot close to the North British Railway-Bridge, where the Marls (which are known to be very thin there) appear to be somewhat disturbed. Nor are there any signs of faults in the Caldew Valley between Carlisle and Cummersdale.

The Lias, where it is visible, appears to consist of dark shale with limestone bands. It is probable that the boring near Great Orton, already mentioned, which showed 210 feet of Liassic beds below 18 feet of Drift, gave also the maximum thickness it attains, as the ground reaches its highest level on the Lias plateau in that neighbourhood, which is very near its centre. The best section in the Lias is in a brook between Great Orton and Flat. It is also visible to a very slight extent in Thornby Brook, and at Quarry Gill, near Aikton. It was at one time supposed to be Carboniferous rock, the result of the existence of an anticlinal, but Mr. R. B. Brockbank found ammonites and other Lias fossils in it. He sent them to Mr. E. W. Binney, who pronounced them Liassic, and soon after visited the district and described it in the 'Quarterly Journal of the Geological Society,' Vol. xv. *Ammonites johnstoni* was found at each of the three places mentioned, a fact which indicates that it probably occurs throughout the mass. This ammonite belongs to the zone of *Ammonites planorbis*, the lowest of the Lower Lias.

Whether Rhætic Beds exist or not is a question which may

perhaps never be decided in this drift-covered, sectionless district. No evidence of any has yet been seen.

From the available evidence, which unquestionably leaves much to be desired, it would appear that this outlier of Lower Lias rests unconformably, partly on the Gypseous Shales, partly on the Kirklington Sandstone, and partly on the Stanwix Marls.

The country occupied by the Lias outlier is so awkward to get at, the sections are so few and so extremely small, and the district generally so wanting in beauty and interest, that no excursion to it has been planned.

Before passing on from this part of my subject to the Superficial Beds, a question of considerable importance concerning the relations of the Permian-Triassic and Liassic rocks to each other demands attention. I have in the preceding pages simply given you my own views as to those relations, stating what the available evidence amounted to, and accepting it as the only possible guide; but some years ago I became aware that my conclusion that the Lias rested unconformably partly on the Gypseous Shales, partly on the Kirklington Sandstone, and partly on the Stanwix Marls, was deemed so startlingly improbable on theoretical grounds by Messrs. Bristow and Aveline that the publication of Sheet 107 S.E. had been suspended for a time in order that other interpretations might be carefully considered, and possibly additional evidence procured. Though fully recognizing the scanty nature of the evidence which had sometimes decided my view this way or that way, I have from time to time protested against certain modifications, on the ground that, whether the local evidence were much or little, we were unquestionably bound to follow it as regards the map, though a chapter in a memoir might well be devoted to the consideration of alternative interpretations. As I now find that the Carlisle quarter sheet (107 S.E.) is on the eve of publication, "with modifications by W. T. Aveline," and as these modifications are entirely based upon the supposed necessity of showing the Lias resting conformably on the Stanwix Marls, I propose to consider briefly, first, the supposed theoretical necessity for these modifications, and, secondly, their practical results.

I am, in the first place, utterly at a loss to understand how

we can expect any series of strata to be found resting invariably on any other given series, inasmuch as it is practically impossible that they can be conterminous. In the case of the Permian-Triassic rocks we have a series of beds which are generally admitted to have been deposited in great lakes, which have varied both in area and in freshness or saltiness from time to time. We find accordingly, as might be expected, a great number of local variations and unconformities in this series, which often make it impossible to speak with certainty as to the correspondence of subdivisions in one district with those in another. Mr. H. B. Woodward, in his paper on "The Permian and Trias" ('Geol. Mag.,' Sept., 1874), writes as follows:—

"Thus it will be seen that there is no very strong evidence for a great break in the Triassic series throughout the British area, but that locally in them, as in the Permian series, there were pauses in deposition, accompanied by some erosion of the beds."

"Pauses in deposition, accompanied by some erosion of the beds," are precisely what we have in the Carlisle Basin. It seems to me evident that the Lower Lias—a marine, shallow-water formation—must naturally be expected to overlie the Trias at these local centres of erosion, as well as elsewhere; and because there are large areas without any local centres of erosion, where the Lower Lias is found lying apparently conformably above the Trias, this furnishes no presumption against the existence of areas where local erosion prevents a similar state of things. Indeed, when we consider the lacustrine origin of the Permian-Trias, and the marine origin of the Lias, it is almost absolutely certain that such local unconformities between them must occur here and there. Therefore it seems to me that the conformity or unconformity of the Lias to the Trias in any given area is a perfectly open question, to be decided in each case by the careful and impartial weighing of the local evidence.

So much, then, for the supposed necessity which has prompted geologists so experienced and respected to make these modifications. I will now proceed to discuss their nature.

The slight amount of evidence in some places, and the utter absence of any in others, allows a singular amount of latitude in this case. It may be remembered that with regard to the

Gypseous Shales, known only by borings at Abbey Town, Bowness, and Orton, I remarked that they rested directly upon the St. Bees Sandstone, west of the Lias, while the Kirklington Sandstone did so east of that formation; and that I considered the Gypseous Shales the earlier in date, because there was no evidence that they were lying unconformably on the St. Bees Sandstone, while there was a fair amount showing that the Kirklington Sandstone did so. For in Carwinley Burn not only were there no Gypseous Shales, but most of the St. Bees Sandstone had also disappeared. In treating of the Stanwix Marls I pointed out that they were seen lying on the Kirklington Sandstone at Cliff Bridge and elsewhere, and showed that at and west of Carlisle the evidence demonstrated that they were exceedingly thin, and extended but a very slight distance south of the Eden.

The modifications are these. By treating the Kirklington Sandstone as simply the upper beds of the St. Bees, and by identifying the Gypseous Shales with the Stanwix Marls, the Lias is seen reposing conformably on the united Gypseous Shales and Stanwix Marls; while, in order to account for the identification of the two, a fault is introduced, bounding the Lias at its northern end, ranging in a north-west and south-east direction, and having a downthrow to the south-west. By this fault the Lias and an increased thickness of the Stanwix Marls are both brought in, together with, apparently, the gypseous material in which the Stanwix Marls northward are deficient. About Carlisle the Stanwix Marls are shown stretching southward to a very much greater extent than the evidence warrants, while on the Beaumont side they spread out to Bowness.

It may be granted that there is a bare possibility that the St. Bees and Kirklington Sandstones may be one, without any unconformity between them, but probability seems to me to be decidedly against it. The Stanwix Marls may also be the Gypseous Shales with almost all the Gypsum left out, but nobody would suppose them to be identical but for theoretical prepossessions. The Stanwix Marls may also, after appearing to be very thin west of Carlisle, suddenly thicken out in the extraordinary way depicted, but it is highly improbable that they do so. Lastly, any scheme which demands, in addition, the

Scale Three Miles to an Inch.

Scale Three Miles to an Inch.

PEAT.

ALLUVIUM AND
RIVER GRAVEL

GLACIAL DRIFTS
AND ROCKS
UNDERLYING
THEM

existence of a great fault, for which there is no evidence whatever, appears to me to be self-condemned. For though, as at Catlands Hill, a fault which is nowhere seen may have its existence made manifest through the juxtaposition of certain beds, which but for it would necessarily be far apart, the invention of a fault where there is no evidence of one, simply in order to obtain a result in harmony with theoretical prepossessions, is, it seems to me, an utterly unsound and unscientific proceeding. It is, therefore, because it appears to me that a map should faithfully reflect the evidence of a district, whether conclusive or inconclusive, and because a different view appears to be held by many geologists of high character and eminence, that I deem it my duty, on this matter of scientific principle, to trouble you with this protest.

FIG. 5.—Section across the Carlisle Basin from Gretna to Warwick.

III.—THE SUPERFICIAL BEDS.

Of the superficial beds the oldest and most important are those known collectively as the Glacial Drift. These beds vary a good deal in composition. The clay known as Till, in which stones of many kinds are mixed confusedly, is not often seen, except on the high ground occupied by the Lower Carboniferous rocks. Nearer the Solway the Glacial Drift appears to thicken, and it certainly covers the surface more uniformly. (See Map, Fig. 6, and Diagram-section, Fig. 7.) Thus, north of the Maryport and Carlisle Railway the only piece of ground of any appreciable size bare, or almost bare, of Drift is a tract of about one square mile between Aspatria and West Newton, in which there are many quarries in St. Bees Sandstone. A bore-hole made 14 or 15 years ago near Abbey Town revealed a thickness of nearly 200ft. of Drift, and, though this thickness may perhaps be exceptional, streams flowing in gorges of 30ft.

or more in depth often show nothing but Drift, and so do railway-cuttings of similar size.

In short, the evidence of railway-cuttings, streams, and farmhouse wells tends to show that north of the Maryport and Carlisle Railway the Drift is usually more than 30ft. thick; and outside that area the amount of surface in which Carboniferous or Permian-Triassic rocks appear is very small, though it increases as we approach the Carboniferous Limestone fells.

Below the fells it soon becomes evident not only that the surface of the ground is almost wholly covered by Glacial Drift, but that the features noticeable are Drift ridges, owing nothing of their shape to the underlying formations. Sometimes over large areas we find regular undulations almost perfectly parallel to each other. In other places these are not so clearly marked, though the contours of the ground testify to the presence of uniformly soft strata. The only spot within the Permian-Trias area where the influence of the underlying rock is manifest in the shape of the ground is where the Lias outlier appears. This outlier is very uniformly covered by Drift, though it is not so thick there as on the lower ground outside it; but the geologist standing at Wiggonby, on the southern edge of the Lias outlier, will see northward of him land of flattened, plateau-like contour, while to the

south he views a country of undulating ridges resembling those in areas westward, where nothing but Glacial Drift can be seen. A well-sinker, living in this district a little southward of the Lias, told me that he had never met with anything in that neighbourhood but sand, gravel, and clay, though he had sunk to depths of 20, 30, and 40 feet in many spots thereabouts.

Good sections in these Glacial Drift beds are very rare, the best I have ever seen having been in the neighbourhood of Carlisle, some years ago, when a great extension of railway-sidings was taking place on the completion of the Midland Line from Settle to Carlisle. The changes in the nature of the beds as the excavations widened were very curious. What had seemed more Till-like than usual one week looked next week more like earthy gravel, and in a third week like sand and gravel, or *vice versâ*. Nests of Till were seen here and there in the midst of sections of gravel. On the whole, the most extensively diffused form of Glacial Drift is what may be styled Earthy Gravel.

Here and there, however, rising above the ordinary Drift-ridges, mainly consisting of Earthy Gravel, are mounds and ridges of clean sand and sandy gravel, which, though they do not occupy any large proportion of the surface, except in certain limited localities, are often very conspicuous where they do appear. These Eskers abound on both sides of the Solway. North of the estuary they may be seen at Cummertrees, and north of the town of Dumfries. In Cumberland the Newcastle and Carlisle Railway crosses an Esker tract between Heads Nook and Brampton, and another exists about halfway between Abbey Town and Allonby. A little group of Esker ridges appears near Crofton Hall, the most prominent of which is a beautifully wooded hill, known as Torkin, which we may perhaps see on the day of our Chalk Beck Excursion, together with a slight ridge south of Dalston Hall. These Eskers, where a section can be seen, look as if they had been heaped up irregularly by marine action. Many hollows which have no outlet exist here and there in the midst of an Esker tract. Whether they occur massed together with outlying mounds and ridges, or simply as isolated ridges, they contrast very much, in their irregularity and boldness of outline, with the regular undula-

tions of the Earthy Gravel. The Eskers, of which Torkin is the most conspicuous, are a group of isolated ridges. See Fig. 8.

FIG. 8.—Eskers, Crofton Hall. (From the 'Geological Magazine,' 1883, p. 440, by kind permission of Dr. Woodward.)

The contrast between the contours of ground occupied by ordinary Glacial Drift and those of an Esker district may be easily seen during the course of a railway journey from Carlisle to Brampton. Between Carlisle and Heads Nook the journey is through a country covered with Glacial Drift of the ordinary type, the contours of the ground being flattened, uniform, and regular. East of Heads Nook we see steep, irregular mounds and ridges, with here and there, in the midst of them, peaty hollows. The tract between Abbey Town and Allonby presents the same general characteristics as that of Brampton, but the Eskers are of somewhat smaller size. East of Brampton, Eskers may be seen up to a height of 700ft. or more, while near Abbey Town the highest only attains a height above the sea of 156ft., though they form the highest ground in that district.

Eskers are found at very various levels, from that of the Raised Beach to a height of 800 feet. Many are scattered here and there between Kirklington and Brampton, and a ridge south of Arthuret Church may be seen during our visit to the Kirklington district. As regards their formation, my own opinion is this. Towards the close of the Glacial Period the whole area was submerged beneath the sea, till ground now 800 feet above it was brought beneath its level. During the submergence much of the Till or Boulder Clay would be converted into gravel more or less earthy. On the emergence of the district much of this earthy gravel would be entirely removed, and

much earthy and clayey matter washed out of part of the rest. This clean, sandy gravel and sand would be here and there heaped up into Esker mounds and ridges, which were, at the time they were formed, analogous in position to the various bars and sandbanks now being heaped up off our coasts. Some persons may ask why subaërial denudation has had so little effect on their forms since the date of their formation, but a little reflection will show that there is no great mystery in the matter. If—to take an illustration from the London District—we inquire why the Lower Tertiary escarpment between Greenwich and Erith is so deeply hollowed out by combs, the answer is obvious. Below the thick mass of Blackheath Pebble-beds capping the escarpment, are the Woolwich Series, which contain thin clayey bands. These hold up the water which percolates freely through the Pebble-beds, and cause its exit in springs here and there along the hillside. Of course the influence of rain on a slope, where this undermining action of springs has been going on for ages, has been most potent, and has produced the remarkable sculpturing of the surface we now see along the course of this escarpment. But in the case of Esker ridges no springs are at work, the whole mass being thoroughly permeable from top to bottom, and resting on more or less permeable strata below; and as, in addition, they contained no soluble calcareous matter, and were probably speedily covered by grass or other vegetation on their emergence, there is no reason why they should not have remained for ages almost entirely unaffected by subaërial denudation.

Before leaving the subject of Eskers it may be well to point out that they are known to exist on the west coast of South America in the desert of Atacama, where neither rain nor rivers can have had any influence on them. My cousin, Mr J. J. Winder, who has been long resident in South America, and to whom I am indebted for information about them, remarks:—"That they are true Eskers can hardly be doubted, as in some places where sections exist the shingle is clearly to be seen heaped up as though by the force of opposing currents." These Esker ridges sometimes rise to a height of more than 200 feet above the plain on which they lie.*

* See "On Eskers or Kames," 'Geol. Mag.,' Oct., 1883.

The peat-mosses in one respect form a connecting link between the Glacial Drift and the river-terraces and alluvial flats, inasmuch as they appear at various levels, sometimes lying in hollows on the Glacial Drift, sometimes being found on the great estuarine flats which border the Solway, as though they rested upon portions of them. These mosses are usually highest in the centre, so as to form a very low dome. Among those on the Earthy Gravel are Bolton Fell, near Hethersgill, Scaleby, Solway, and Oulton Mosses. Oulton Moss, near Wigton, occupies the greater part of the site of a small lake, only a small part of which remains unfilled by peat. Old maps also show a lake near Cardurnock, at the south-western end of the large peat-moss which occupies the greater part of the Bowness peninsula. Diligent search in these last-named localities might, perhaps, reward the investigator of ancient lake-dwellings.

Besides the mosses already named, there are Drumburgh Moss, Wedholme Flow, that drained by Holme Dub and Black Dub, and some others.

A glance at the alluvial flats of the various streams, from the Caldew westward, shows that the rivers of this district have been in the habit of changing their courses from time to time, as the flats communicate with each other in the strangest way. If we take the Caldew, for example, we find that it now flows nearly due northward into the Eden at Carlisle; but at Dalston there is evidence in the flat of river-gravel which forms the water-parting between its present course and that pursued by the various streams which run westward into the Wampool, that the Caldew once, when flowing at a somewhat higher level, took a westerly turn at Dalston instead of a northerly one. There is a similar connection between the flats of the Wampool and the Waver, north of Wigton; and though we can walk from Abbey Town to Allonby on what seems to be one continuous alluvial flat, whether peaty or not, we find that while Holme Dub flows northward into the Waver at Abbey Town, Black Dub discharges itself into the sea at Allonby. If we look at the great low-lying peat-mosses and their distribution, and also note the amount of more or less peaty soil outside the area that can fairly be called peat, it be-

comes evident that these peat-mosses were once considerably larger than they now are, and that changes in the courses of the rivers may have done much to diminish their size. For example, Bowness and Drumburgh Mosses were once probably continuous, but have been separated either when the Eden took a south-westerly course towards Kirkbride, or the Wampool a north-easterly one towards Easton.

The most interesting peat-moss historically is Solway Moss, situated in what used to be known as the Debateable Land, the country between the rivers Esk and Sark. Close to it occurred the surprise and rout of the Scottish army in 1543, when many of the fugitives were lost in its treacherous depths. On the night of November 16th, 1771, Solway Moss burst, and, flowing over the edge of the elevated ground on which it rests, covered 500 acres of the broad alluvial plain of the Esk. No human lives were lost, but many cattle were destroyed. (See Hutchinson's 'History of Cumberland,' Vol. ii, p. 542.)

There are many small peat-mosses north of Carlisle, between the Eden and the Esk and Line. No lakelets are now found there, though some which once existed have been drained, and are now represented by alluvial flats. The turnpike road between Carlisle and Gretna crosses many of them. This network of what were once either lakes or morasses must formerly have given much additional strength to the Border City. Hutchinson, writing a century ago, records the existence of a small lake in the parish of Rockcliff.

The large peat-moss known as Wedholme Flow is situated in the parish of Holm Cultram or Abbey Town. Of this parish Hutchinson records:—"There is little wood, except a few trees about the dwelling-houses;" but we learn that in the time of Queen Elizabeth it was enacted that the tenants of the manor were to have the wood growing in Wedholm Wood for the repair of the sea-dykes. Perhaps the cutting down of trees for this purpose may have led to the blowing down of large numbers of the others during storms. This would obstruct the drainage, and give rise to a morass in which trees would not grow, but which would be highly favourable to the growth of peat-moss. Hence possibly, as in so many other cases, the

total disappearance of Wedholme Wood, in spite of provision to ensure "the better preservation of the woods," and the enlargement of Wedholme Flow.

As regards the existence of submerged forests or peat-mosses in the Solway, Camden remarks of Bowness:—"That the figure of the coast hereabouts has been altered, appears plainly from the roots of trees, covered over with sand, at a good distance from the shore, which are often discovered when the tide is driven back by strong winds." On inquiring in 1880 of Mr. R. B. Brockbank as to whether any submerged forest had been recently visible, he replied:—

"I found an intelligent old man, Robert Johnston, who told me that fifteen or sixteen years ago the channel, which shifts about very much in cutting its way into the sand, formed a steep bank on one side, on the edge of the wide flat of sand which stretches away from Cardurnock towards Criffel, and laid bare three or four feet of peat, below five or six feet of sand." Wood was found embedded in this peat. But the channel, when Mr. Brockbank wrote, had again shifted, and nothing could then be seen but an unbroken sandy flat.

A slightly elevated Raised Beach, often more or less covered by Blown Sand, extends from Bowness to and beyond Cardurnock. Crossing the estuary of the Waver and Wampool, we find Skinburness, Sillioth, and Allonby all situated upon it, and it extends some distance southward of them. Thus we have in this district evidence both of geologically recent upheaval and of subsidence. The probability is that the upheaval of the raised beach elevated the land to a somewhat greater height than it now has, and that a slight subsidence has since occurred, and reduced the district to its present level.

Where the Raised Beach can be seen unobscured by Blown Sand, the shingle ridges of which it consists may be observed ranging in a direction nearly parallel with that of the present coast-line. At Campfield, two miles west of Bowness, two of these ridges, more strictly parallel to each other, and sharper in outline than usual, deceived the Ordnance surveyors into a belief in their artificial origin, and caused them to draw two connecting lines at right angles to these ridges, and to add the

words, "site of camp." However, the geological visitor will have little difficulty in seeing that the northern and southern sides of the supposed camp are really natural shingle digers, and that there are no signs whatever of any ridges connecting them. Mr. R. S. Ferguson, of Carlisle, remarked of some exploratory diggings carried on there in 1880 that they revealed nothing to indicate the Romans, and nothing to indicate a camp, but the name.

But of all formations the Eskers offer by far the most likely field of controversy between antiquarians and geologists. For sometimes (as in the case of Torkin) an obscure Esker ridge swells out so suddenly both in height and breadth as to be calculated to deceive the most careful observer for a time. In other places isolated Esker mounds present the appearance of large tumuli. On the other hand, a natural tumulus may well have been looked upon as a suitable spot for the interment of a chief in prehistoric times. Yet no evidence of such burial might reward the explorer of our days, as the highly permeable Esker sand and gravel would allow the removal, by the action of rain-water, of everything but stone implements and pottery fragments.

Before concluding, I must not omit some remarks on the changes perpetually taking place in the channels of the Solway, and their consequences. The chief channel is that resulting from the union of the rivers Esk and Eden, but the position of this junction and that of the united channel is perpetually varying. This has caused a rapidity of growth and decay in certain ports on the Solway which has probably not been equalled anywhere else on our shores. For example, in 1301 Skinburness was a port of some consequence, having been a chief place for the King's magazines when expeditions against Scotland were taking place. It was accordingly made a free borough by King Edward I. But in 1305 the Abbot of Holm Cultram applied for leave to have a market and fair at Kirby Joan (now Newton Arlosh) instead, and in the grant made in consequence of that petition it is stated:—

"That the abbot had reported that a great part of the road leading to the borough (of Skinburness), and much of the borough itself, by divers invasions and storms were wasted; and that the inlets of the sea were become so deep that people

could not resort hither, or inhabit the place, as before, on which account the abbot had petitioned that the village of Kirby Joan should be created a borough, with the like liberties and privileges as Skinburnesse had before held."

A change in the direction of the chief channel of the Solway, which should restore the state of things existing in the year 1840, would give Skinburness the same advantages over neighbouring places which it possessed in the year 1301. The deep channel close to the town in King Edward's time probably came at last to eat into the soft materials of which the shore is composed, while its existence would enable the sea to act with much greater force on the coast thereabouts during storms. Hence the suddenness of the destruction of the rising port. The road leading to it must have been along the raised beach close to the shore, on which the road between Skinburness and Maryport now lies. From Old Mawbray northward the Raised Beach has marshy ground on the land side, which would have been very unsuitable for a road; and the Romans doubtless connected their camps at Moresby, Maryport, and Beckfoot by means of a road along the Raised Beach. It seems almost certain that this road would be continued northward as far as Grune Point, and by no means improbable that it was thence connected with another from Cardurnock to Bowness by means of a causeway which would give a safe passage at low tide. Camden (quoted by Hutchinson, Vol. ii, p. 485) says of Bowness:—

"The inhabitants at this day called it Bulness; and though it is but a very small village, yet it has a fort, and (as a testimony of its antiquity) besides the tracks of streets and pieces of old walls, it has a harbour, now choaked up, and they tell you that a paved causeway ran along the shore from thence as far as Ellenborough."

But while the remains of mediæval Skinburness are to be looked for under the present foreshore, a very different fate has been that of Port Carlisle, about a mile east of Bowness. As its name implies, it was intended that it should form the port for Carlisle; a canal was made between the two places, and opened in 1823; but the Solway channels, favourable when the canal was being made, speedily altered their position, and

the harbour became silted up. The canal became the site of a railway in 1854, and in 1856 this railway was continued from Drumburgh to Silloth, the newest of the Solway ports, about one and a half miles south of Skinburness. The first dock at Silloth was constructed in 1857, and another has recently been made there. The 'Carlisle Journal' of April 1st, 1881, contained an interesting paragraph on a 'Change in the Channel at Silloth,' in which it is stated:—

"The bed of the channel near Silloth jetty is gradually returning to the position it occupied when the Silloth Dock was formed. . . . Very soon after the dock was formed the channel commenced to recede from the jetty. It continued to recede, the sand accumulating at the end of the pier to the height of 20ft. There had been a depth of 16ft. of water at this point, and the alteration in the bed of the channel created inconvenience to steamboats in landing passengers. A dredger was employed in keeping open the channel. About two months ago it became evident that another change had set in, the accumulation of sand at the end of the jetty appearing to be getting less. Since that the sand has been gradually cleared away, and now there is again 16ft. of water at the jetty end, enabling steam-boats to land passengers there at all times of the tide."

Let us hope that Silloth, unlike its predecessors, Port Carlisle and Skinburness, is destined to

Suffer a sea-change
Into something *rich* and strange.