to no- I am ~~anxious~~

anxious to get such

men as yourself who are

well known.

Yours very truly,

Private & Conf.

I did not expect the

Duke to subscribe and

wish I could manage

to do that for him

& still retain his name

Feb 5. 1873.

J. Campbell

Hall
Geology & Faults

Look to page 324
for a section with a
Surface cutting
through all manner of
veins. viz the Strata
and please return to
J. F. Campbell
March 16. 73

3.

[*From the* Quarterly Journal *of the* Geological Society *for August* 1868.]

J. Campbell Esq
Of Islay
From the Author

On the Thickness *of the* Carboniferous Rocks *of the* Pendle Range *of* Hills, Lancashire, *as illustrating the Author's views regarding the* "South-easterly Attenuation *of the* Carboniferous Sedimentary Strata *of the* North *of* England." By Edward Hull, Esq., M.A. (Dublin), F.R.S., F.G.S., of the Geological Survey of Scotland *.

In the following paper I purpose bringing forward some new facts recently ascertained in the district of Burnley and the Pendle Range, in confirmation of certain views advanced on a previous occasion, regarding the relative distribution of the "sedimentary" and "calcareous" strata of the Carboniferous series in the North of England. These views are published in the Journal of this Society †; and as introductory to the matter in the present communication I must ask permission very briefly to recapitulate them.

In the paper referred to, I endeavoured to prove that to the north of an old neck of land, or "barrier," which stretched across the centre of England from Shropshire, and which was formed of Silurian and Cambrian rocks, the Carboniferous strata were deposited originally upon the following plan:—On the one hand, the calcareous member (the Mountain-limestone) attained its greatest vertical development along the northern flanks of this barrier in Derbyshire, and thence thinned away northward and westward, and, as had been long since pointed out by older geologists, became intercalated with sandstones, shales, and beds of coal in the North of England and Scotland, where it appears in its most debased and attenuated form; on the other hand, the sedimentary beds of sandstone, shale, &c. were deposited in greatest force towards the north-west, diminishing in thickness towards the south-east of England,—the development of the one set of strata being in the inverse ratio of that of the other.

* Communicated with the consent of the Director-General of the Geological Survey.

† Vol. xviii. p. 127.

This plan of relative distribution was illustrated on the map of the country by a series of lines of equal thickness (or *isometric* lines), which, I venture to think, renders the arrangement of the two sets of strata very simple and intelligible.

Confining my observations to the district north of the central "barrier" of Silurian rocks, and taking, as examples of the south-easterly attenuation (or thinning out) of the sedimentary beds, the cases of Leicestershire and South Lancashire as ascertained by the carefully measured sections of the Geological Survey, I gave the following results:—

	Thickness.
Leicestershire	3100 feet.
South Lancashire	12800 „

This augmentation of the same beds in Lancashire, as compared with Leicestershire, appeared sufficiently striking; but subsequent investigations, while engaged in the survey of the district further north along the Pendle Range and in the neighbourhood of Burnley and Blackburn, have shown me that it falls short of the full measure of increase by several thousand feet of strata.

For some years past the geological surveyors have been authorized to trace each separate bed of gritstone or conglomerate in the Millstone and Yoredale series; and these are represented in the published maps and sections by distinctive tints and patterns. By such means alone could a true knowledge and representation of the structure of the Lower Carboniferous rocks be arrived at; and it is only after having, with my colleague Mr. Tiddeman, traced these beds through many miles of country, and ascertained their true relations to each other, and their relative and absolute thickness by several comparative sections, that I venture to give publicity to the results they point to. The details, however, of these sections are primarily the property of the Geological Survey, and are to appear in due course in the Memoirs; and this being so, I must claim some amount of indulgence during the interval, and offer only the gross aggregate, as it were, preparatory to a future statement of the individual thickness of the beds. I can venture to assert, however, that the statement I now make will not be found far from the truth when the balance-sheet is presented.

I have made three transverse sections for the purpose of ascertaining the thickness of the Millstone-grit series, with the following results:—

Sections of the Millstone-Grit series, Pendle Range.

Locality.	Thickness.	Mean thickness.
1. Sabden, near Burnley	6500	5500 feet.
2. Whalley Nab	5000	
3. Snodworth, near Blackburn.....	5000	

As the Sabden section is so much greater than the other two, I do not feel so much confidence in it; but if there is a real exaggeration, it is reduced by taking the mean of the three thicknesses.

The results above stated will not appear unreasonable when it is

known that the Millstone series forms a range of hills with an average breadth of a mile and a half, in which the beds dip at angles varying from 30° to 50°, or even more. The Yoredale series occupies a tract of country nearly as broad, with the addition to the thickness derived from a rise in the ground in the direction of the dip. The inclination of the beds is nearly as great as that of the overlying Millstone-grit series.

The thickness of the Yoredale series has been ascertained with much precision by my colleague Mr. Tiddeman, from very clear and continuous sections in the neighbourhood of Clitheroe. Throughout the whole series of grits and shales, there occurs only 350 feet of limestone and occasional thin earthy calcareous bands. The thickness of the entire series, exclusive of the limestone above referred to, is no less than 4675 feet. If, therefore, we add to this the Millstone-grit, we get the following results:—

Thickness of Millstone-grit series	5500	feet.
Thickness of Yoredale series	4675	„
Total.....	10175	„

In order to ascertain the entire development of the Carboniferous series in this district, it is necessary to add the thickness of the Lower, Middle, and Upper Coal-measures. Unfortunately for our purpose, a portion of the Middle and the whole of the Upper Coal-measures are absent from the Burnley district, having been denuded off from that area. There is, however, no good reason for supposing that these Upper beds were not originally deposited here, as there is no sensible break in the series between the Middle and Upper Coal-measures of Lancashire. I think, therefore, I shall be entirely justified in going a few miles to the southward, where these beds occur, and adding the measure of their thickness to that of the underlying beds at Burnley. Taking the thickness as fully ascertained in the neighbourhood of Manchester*, we obtain the following grand sum for the Carboniferous Rocks in Mid-Lancashire as originally deposited:—

Thickness of the entire sedimentary beds, as originally deposited in the Burnley district.

			Thickness in feet.
Coal-measures	Upper Coal-measures	(Ardwick, &c.)	2013†
	Middle „	(part at Burnley)	4247
	Lower „	(Burnley)	2200
Millstone-grit series		(as above)	5500
Yoredale series		(as above)	4675
Total			18635

* "Geology of the Country around Oldham and Suburbs of Manchester," Mem. Geol. Survey; also Quart. Journ. Geol. Soc. vol. xviii. p. 140. The thickness of the Coal-measures there given is 7200 feet; but this does not include the full series of the Upper Measures under Manchester, as the upper limit is concealed beneath the Permian formation.

† This is not the entire thickness, as higher beds are concealed by the uncon-

So that, in round numbers, considering that we nowhere reach the upper limit of the Coal-measures, we may take the combined thickness of the sedimentary materials at 19,000 feet as originally deposited in this part of England.

We have now to compare these measurements with others taken at intervals along a south-easterly line, or along the direction of attenuation, Leicestershire being the extreme point where the comparison can be made in the case of the Carboniferous rocks. The thickness in these cases are also taken from sections of the Geological Survey—some measured by Mr. A. H. Green, some by myself*.

Comparative vertical sections of the Carboniferous strata from North Lancashire to Leicestershire.

N.N.W.	Burnley district.	Mottram district.	North Staffordshire.	S.S.E. Leicestershire.
Coal-measures	8460	7635	6000	3000
Millstone-grit series ..	5500	2500	500	50
Yoredale series	4675	2000	2300	50
	18635	12135	8800	3100

From the above comparative sections it will be observed that the beds which attained so prodigious a development in North Lancashire dwindled down to one-sixth of their volume in Leicestershire, in Central England, near which place the Mountain-limestone attains a great but unknown thickness†.

In fact, the development of these beds in North Lancashire has surpassed that of the contemporaneous beds of South Wales, hitherto considered to present the largest vertical series of Carboniferous sedimentary rocks in the British Isles; and, as far as we know, it is only exceeded in Europe‡ by that of the Coal-field of Rhenish Prussia, where the beds, according to the estimate of Herr von Dechen, reach a thickness of over 20,000 feet. Turning to the continent of America, and taking the series of Nova Scotia as representing the maximum accumulation of sedimentary beds, we find that it is exceeded by that of North Lancashire, though, as Dr. Dawson has shown, the section is incomplete, and scarcely presents a fair point of comparison.

Professor Phillips, in his 'Geology of Yorkshire,' observes, "the thickness and purity of the argillaceous deposits being to the west,

formable overlap of the Permian and Trias at Manchester, as shown by Mr. E. W. Binney, F.R.S. See "Geology of the Country around Oldham and Manchester."

* Messrs. Hull and Green "On the Millstone-grit of North Staffordshire," &c., Quart. Journ. Geol. Soc. vol. xx. p. 242 *et seq.*

† At least 4000 feet, according to sections which I levelled in the neighbourhood of Ashbourn.

‡ After reading the description in Sir R. Murchison's work on the Geology of Russia, I was under the impression that the beds in the coal-field of the Donetz attain a greater vertical thickness; but, from some statements by Sir Roderick himself, I found my opinion was incorrect.

and the same qualities belonging to the gritstones in the north, we may venture to suggest, as an explanation, the entrance of two distinct currents or primeval rivers, one on the west bearing sediment from the surface or region of argillaceous slate, the other from the north bearing almost wholly the granular detritus of regions abounding in gneiss and mica slate"*. Though this distinction in the distribution of the clayey and sandy members of the formation is doubtless correct in its application to Yorkshire, I doubt if it holds good with reference to the whole of the north and centre of England, where the thinning away or the swelling out of both sets of beds seems to proceed *pari passu*†. It therefore seems to me clear that we must attribute the source of the sediment generally to one and the same primeval Atlantis; and this view is strengthened by the fact that the Carboniferous sedimentary strata swell out towards the north-east of America on the shores of Nova Scotia, and tail away towards the south and west of that continent.

Observations on the Relative Ages *of the* Leading Physical Features *and* Lines *of* Elevation *of the* Carboniferous District *of* Lancashire *and* Yorkshire. By Edward Hull, Esq., M.A., F.R.S., F.G.S., of the Geological Survey of Scotland‡.

The approach to completion of the Geological Survey of South and Mid-Lancashire enables me to draw up the following observations on the ages of its physical features. This district, it may be observed, lies immediately to the south-west of that which has been so faithfully illustrated by Professor Phillips in his well-known 'Geology of Yorkshire.'

The most prominent feature of the tract now to be considered is Pendle Hill (1831 feet); and as this hill is but the culminating point of a long range of parallel escarpments, physically one, stretching through a distance of 30 miles from W.S.W. to E.N.E. in Lancashire, and continued into Yorkshire, I shall take the liberty of applying the term "Pendle Range," to the whole of this line of hills.

This range commences at Parbold Hill, near Ormskirk, on the south-west, takes a straight course into Yorkshire by Hoghton Tower, Blackburn, and Whalley, and, forming the south-easterly side of the Vale of Clitheroe, continues its course towards Colne and Skipton. It generally consists of a double group of ridges, often rocky and serried, ranging in parallel lines, with intervening valleys.

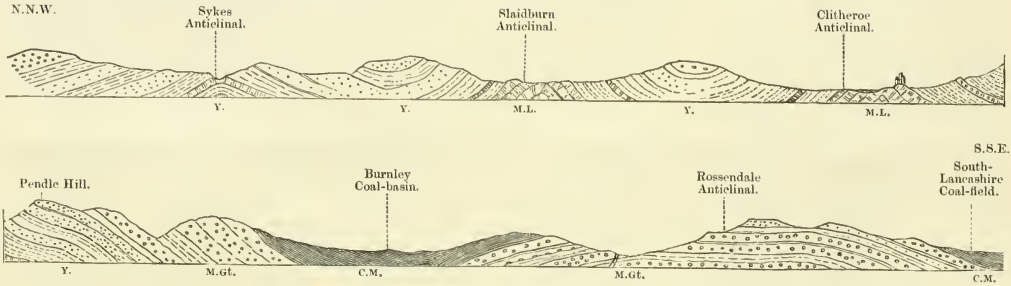
The chain, when cut through transversely near its centre, presents in structure the segment of a great arch (see fig. 1) of which the axis passes by Clitheroe, and along which the Carboniferous Lime-

* 'Geology of Yorkshire,' New Edit., Part 2, p. 188.

† For instance, the uppermost bed of Millstone-grit, or the Rough Rock, reaches a thickness of about 450 feet at Hoghton Towers, near Blackburn, one of the most *westerly* points to which we can trace it; while its average thickness is about 100 or 150 feet.

‡ Communicated with the consent of the Director-General.

Fig. 1.—*Section across the Pendle Range and adjoining district, illustrating the Præ-Permian Flexures of Lancashire.*



M.L. Mountain-limestone. M.Gt. Millstone-grit.
Y. Yoredale series. C.M. Coal-measures.

stone reaches the surface. This axis may be traced from the banks of the river Darwen, near Roach Bridge, through Mellor, Clitheroe, by Skipton and Bolton Abbey into Knaresborough Forest, as indicated in Professor Phillips's Map of Yorkshire*. Pendle Hill is in reality the southern segment of the arch.

North of the Clitheroe arch, there are at least two other lines of elevation, with corresponding troughs, also indicated by Professor Phillips, and recently surveyed in detail by my colleague, Mr. Tiddeman, to which he gives the names of "the Slaidburn," and "the Sykes anticlinals," the intervening synclinal being formed by Longridge Fell.

To the south of the Pendle Range there is a wide trough, giving origin to the Burnley Coal-basin †. The northern side of this trough is formed by the Pendle range itself; and the axis passes through Blackburn, Clayton-le-Moors, Gawthorpe Park, and Marsden, in a general direction from W.S.W. to E.N.E.

The southern side of this basin is formed by the uprising of the Millstone-grit along a very flat arch, which divides the Coal-measures of the Burnley and Blackburn trough from those of the main coal-field of South Lancashire. As the centre of this arch passes through Anglezark Moor, and through the ancient Forest of Rossendale, in an E.N.E. direction, along which line the strata are nearly horizontal, I propose calling it "the Rossendale Anticlinal" (see figs. 1 & 2). To the south of this arch the beds roll over and dip under the South-Lancashire coal-field, which sets in by Rivington, Bolton-le-Moors, Bury, and Rochdale. The general arrangement of these flexures will be understood by reference to the diagrammatic plan (fig. 2, p. 326).

Thus we see that the Carboniferous strata of this part of Lancashire were originally forced into a series of foldings along lines ranging a little north of east, and south of west, by the exertion (it may be supposed) of lateral pressure, which seems to have produced its most powerful effects along the line of the Pendle range. The uprising of the beds along the low arch of Rossendale can only be regarded, as it were, as the swell from the distant wave ‡. These several flexures are expressed in the diagram-section (fig. 1), details being omitted.

In considering this section, the physical geologist will not fail to observe how the valleys lie in the lines of the stratigraphical hills or arches, and the hills in the lines of the stratigraphical valleys, or troughs, the only exception being the Burnley Basin. The flexures are somewhat disarranged in places by transverse faults, but on the whole are well defined.

Geological age of the flexures.—The next point to be determined is the geological age of these flexures; and fortunately for our purpose

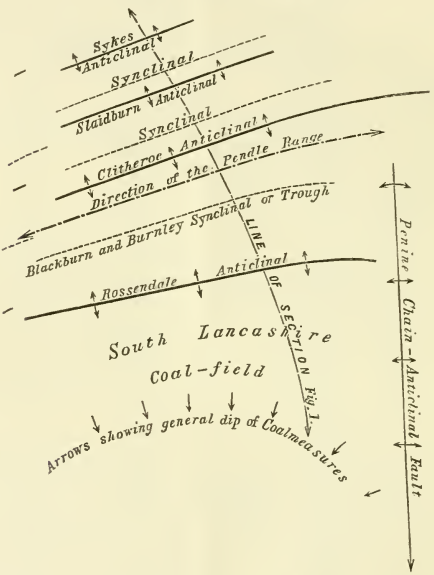
* 'Geology of Yorkshire.'

† The position of the Burnley Coal-basin, lying between Pendle and Boulsworth Hills, is shown on the section accompanying Conybeare and Phillips's 'Outlines of the Geology of England and Wales,' 1822.

‡ Along the Vale of Clitheroe, not only are the beds inclined at high angles, but they are highly contorted.

the evidence is clear, and may be considered conclusive. It can be shown that they are the effects of the *earliest of the three consecutive periods of disturbance, to which all the principal flexures and faults of the district may be referred.*

Fig. 2.—*Diagram of Flexures, Mid-Lancashire.*



If we glance at a map of Yorkshire on which the flexures to the North of the Yorkshire coal-field are laid down*, we find that those of the Pendle range are but the extension of others in the region to the east; and I have already remarked that the Clitheroe anticlinal is continuous with that which ranges by Skipton into the Forest of Knaresborough. The uprising of the Millstone and Yoredale series, along the northern margin of the Yorkshire coal-field, can only be regarded as a result of the same movements which have originated the flexures in the Clitheroe and Pendle districts of Mid-Lancashire; and as the Permian beds pass across denuded edges of the Carboniferous rocks, the flexures by which they are influenced are consequently anterior to the Permian period. This is, of course, a fact long since established; but it is necessary to my argument to repeat

* I refer particularly to Phillips's map in the 'Geology of Yorkshire.'

it here, because it shows, by reasoning backwards, *that the Lancashire flexures are also anterior to the Permian period.*

But besides this indirect, there is also direct evidence of the age of the flexures in Lancashire. At several points along the northern flanks of the Pendle range, we find patches of more recent strata, resting on the denuded edges of the Carboniferous rocks. Some of these may be of Triassic age; but, beyond question, others are referable to the Permian age, such as the red sandstones and magnesian limestones of Skillaw Clough and Bentley Brook, near Bispham, described by myself in one of the memoirs of the Geological Survey *. These Permian beds rest on others belonging to the Millstone-grit series, near the south-western termination of the Pendle range of hills. Now, from the known thickness of the Carboniferous series in this part of Lancashire, we may calculate approximately the amount of denudation before the deposition of the Permian strata; for as these latter rest on the lower beds of the Millstone-grit, and as there does not appear to be any material break in the succession of the Carboniferous strata, it is clear that there must have been swept away part of the Millstone-grit series, and the whole of the Lower, Middle, and Upper Coal-measures, amounting to nearly 10,000 feet of strata, which may be classified as follows:—

	feet.
Upper, Middle, and Lower Coal-measures	8400
Millstone-grit series (in part only).....	1500
Total quantity denuded	9900

The above seems a large estimate, but it is not overdrawn; and it will be recollected that in my former paper, on the thickness of the Carboniferous rocks in Lancashire, I have given the details of the above measurements. The following ideal section (fig. 3), showing the relative position of the Permian and Carboniferous beds at Parbold Hill, will render my observations more plain.

It will be observed that at the foot of Parbold Hill the Permian beds of Skillaw Clough rest on the denuded edges of the Millstone series, but are again found resting unconformably on the Upper Coal-measures south of the Wigan coal-field. It is clear therefore that the whole of these Coal-measures, together with part of the Millstone series, amounting to several thousand feet, have been swept away previously to the deposition of the Permian beds along the northern boundary of the coal-field. This uprising of the Millstone-grit at Parbold Hill is merely the prolongation of the Pendle range, as stated above (p. 323).

With the proof afforded by the Permian beds at Bispham of the age of the upheaval and denudation of the Carboniferous Rocks at Parbold Hill, at the extreme west of the Pendle range, and with the evidence of the Permian beds of Yorkshire at the opposite end, it is of little importance to my purpose what may be the ages of

* 'Geology of Wigan,' 2nd edit. (Mr. Binney, F.R.S., fully admits these beds to be of Permian age.)

several disconnected patches of newer formations, which are found at intervals resting on Lower Carboniferous rocks. I shall not, therefore, stop to discuss the age of the sandstones of Roach Bridge, near Blackburn (which, Mr. Binney, F.R.S., considers, probably belong to the Permian series*), nor of the sandstones of Low Moor, near Clitheroe (which will properly form the subject of a future memoir of the Geological Survey). I shall only assume them to be either of Permian or Triassic age, a fact which is beyond controversy, for the purpose of offering another illustration of the enormous denudations which have taken place before the Triassic, and probably before the Permian period, in the Vale of Clitheroe, at the base of the Pendle Range of Hills †.

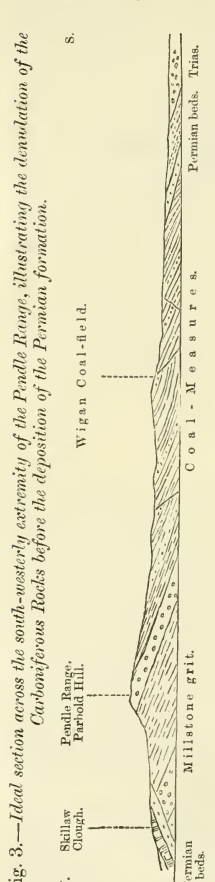


Fig. 3.—*Ideal section across the south-westerly extremity of the Pendle Range, illustrating the denudation of the Carboniferous Rocks before the deposition of the Permian formation.*

Referring to my former paper‡ for the thickness of the Carboniferous series at this place, and premising that the red sandstones of Low Moor rest on the contorted edges of the Carboniferous Limestone beds, it is clear that the amount of strata denuded at this place is that of the Coal-measures, Millstone and Yoredale series, and part of the limestone itself, as follows:—

	feet.
Upper, Middle, and Lower Coal-measures	8460
Millstone-grit series	5500
Yoredale series	5000
Carboniferous limestone (in part)	250
	19210

or nearly 20,000 feet vertical of strata, an amount of materials at the waste of which one feels as much astonishment as at the gathering together of it. And if (as is most probable) this denudation took place

* "Further observations on the Permian and Triassic strata," &c., Mem. Lit. and Phil. Soc. Manchester, vol. iii. 3rd series.

† I regret not being at liberty to give a fuller account of the Low-Moor sandstones, which were formerly regarded as Carboniferous, but have been determined by Mr. Tiddeman and myself to be of later age. A full account will be given in a future memoir.

‡ "On the thickness of the Carboniferous rocks of the Pendle Range," *supra*, p. 321.

in the interval between the Carboniferous and Permian periods, it cannot fail to impress us with some idea of the prodigious lapse of time necessary for the accomplishment of such a result—a lapse of time, it may be remarked, which is not represented by any known group of rocks. Here, indeed, is a blank in the 'Geological Record' waiting to be filled up.

Along the southern margin of the Lancashire coal-field we have examples of Permian strata resting unconformably on Carboniferous, as Mr. Binney, F.R.S., has clearly shown; but the amount of denudation there is inconsiderable as compared with that along the northern flanks of the Pendle range.

I regard it, therefore, as proved that the northern limits of the Lancashire and Yorkshire coal-fields were determined before the Permian period, and at a time when both these coal-fields were still united; for, as I shall presently endeavour to show, the uprising of the Pennine chain did not take place till a later period, namely, after the close of the Permian. In this case the Pendle range, together with all those lines of flexure ranging across the north of England, take rank in time next to the North-Wales, Charnwood-Forest, and Cumbrian groups of hills. I shall now proceed to discuss the question of the age of the Pennine chain.

Age of the Pennine Chain.—At the time when Conybeare and Phillips* applied this term to the central range of hills which extend in a north-to-south direction from the borders of Scotland to the banks of the Trent in Derbyshire, no distinction had been attempted between the Permian and Triassic formations. Now that we are aware of the relations and important differences between these two groups of rocks, it is time to inquire to what period, whether that before or that following the Permian, the uprising of the Pennine range is to be referred; and, as far as I have been able to ascertain, the attempt has not yet been made.

It is indeed universally admitted that the upheaval of the rocks of the Pennine chain and their subsequent denudation are of older date than the Trias, since the beds of this latter formation overlap the highly inclined Lower Carboniferous strata all along the southern extremity of the Derbyshire hills; but the relations of these Carboniferous beds to those of the Permian stage are not so apparent, and require special investigation.

With this object in view, it is necessary to trace the course of the axis of upheaval of the Pennine chain as it occurs in Lancashire, Cheshire, and Staffordshire, which will only require short notice here, as my colleague, Mr. A. H. Green, and myself have described its course and effects on a former occasion in the Journal of the Geological Society†. We have traced this line of fracture from the neighbour-

* 'Outlines of the Geology of England and Wales.' The authors adopted this term from the Roman name supposed to have been applied to this range of hills.

† E. Hull and A. H. Green "On the Millstone-grit," &c., Quart. Journ. Geol. Soc. vol. xx. 1864; also "Geology of the country around Stockport, Macclesfield, &c.," Mem. Geological Survey, by the same authors.

hood of Colne on the north to Leek and Wetley on the south, a distance of 55 miles; and in the memoir above referred to have termed it "the anticlinal fault," because it is nearly everywhere accompanied by a reversal of the dip.

Commencing on the north at Colne, "the anticlinal fault" traverses the western slopes of Boulsworth and Black Hambledon; crossing the Vale of Todmorden, it follows the margin of the high moorlands of West Yorkshire, throwing off the Millstone and Yoredale beds to the east and to the west. It then passes along the western base of Blackstone Edge, and follows the centre of Saddleworth Valley, and the moorland slopes east of Staleybridge, to Harrop Edge, accompanied by a sharp reversal of the dip. From this point it continues its course by Compstall, Disley, and along the anticlinal axis of Saltersford Valley, onward to Leek in Staffordshire; and here it passes below undisturbed beds of the New Red Sandstone, which lie in the centre of an old palæozoic trough. To the southward of this outlier it reappears, passing along the vertical beds of "Wetley rocks," and ultimately forms a junction with another fault, which traverses both Carboniferous and Triassic beds.

Now here we have the curious case of the same fault passing below the beds of the New Red Sandstone at one point without fracturing them, and coalescing with another fault which does fracture the beds of this formation. It would therefore appear as if the anticlinal fault was of two periods. I wish to draw special attention to this fact, because it is necessary to my argument.

The position and relations of the anticlinal fault with reference to the New Red Sandstone at Leek show that the primary and main fracture, and the great upheaval of the rocks of the Pennine chain which accompanied it, was of older date than that formation; but now we must endeavour to ascertain its relation to the Permian beds.

Throughout a great part of its course from Staleybridge southward, the anticlinal fault is accompanied by several parallel fractures and foldings of the strata, such as the well-known Goyt trough of Farey. These foldings are all closely connected, both by parallelism and other circumstances, with the anticlinal fault, which may be regarded as the axis of disturbance of the whole*. Amongst these parallel lines of disturbance, ranging from north to south, is the "Red-Rock fault"—an important fracture—forming the boundary between the Carboniferous and more recent formations, from Bredbury and Poynton, in Cheshire, southward for several miles. East of Stockport this fault is a downthrow of the Permian sandstone against the Carboniferous beds, and is therefore clearly of later date than the Permian formation itself; and if I am justified in assuming that the "Red-Rock fault" is contemporary with "the anticlinal fault," it is clear, by implication, that "the anticlinal fault" is also of later date than the Permian formation.

An objection to the view of the præ-Triassic age of the "Red-Rock

* Sections illustrating the relations of these flexures will be found in the paper above quoted, by Mr. Green and myself, in the Journal of the Society, vol. xx.

fault" here presents itself; for this "fault" not only dislocates the Permian strata, but those of the New Red Sandstone also, near Macclesfield and Congleton; and it might hence be inferred that the fault is of later date than both of these formations. My answer to this objection is that there have been two periods of vertical movement along the line of the fault—one before the Triassic period, another after. Such cases (where the demonstration is perfect) are not unknown, and I can point to that of the boundary fault of the Coleorton coal-field in Leicestershire, along which there have been two distinct vertical movements in opposite directions, in post-Carboniferous and post-Triassic times. I have also already referred to the case of the "anticlinal fault" at its southern extremity and at Leek as a case of a double vertical movement.

The objection, therefore, which might be urged against the view of identity in age of the "Red-Rock" and "anticlinal" faults, owing to the displacement by the former of beds of Triassic age, seems to me to fall to the ground. Their parallelism and evident connexion with the system of flexures which range in north and south lines seem to me to point to identity of age, from which I draw the conclusion that the age of the "anticlinal" fault and of the upheaval of the Pennine chain is that which intervened between the close of the Permian and the commencement of the Trias—in other words, that it belongs to that period of general stratigraphical disturbance which marked the close of the Palæozoic age. This is a conclusion, indeed, which has often been assumed, but it is not by any means so easily proved.

If, then, my reasoning be admitted, it follows that the Pendle range and the Pennine range belong to two entirely different lines of disturbance—different in direction, different in age—the former being referable to the close of the Carboniferous, the latter to the close of the Permian age. To these two periods Professor Sedgwick refers the Craven and Pennine faults of Yorkshire; and looking at the parallelism in direction of the great fault which forms the boundary between the Carboniferous and Silurian rocks of the central valley of Scotland with that of the Pendle range, it seems highly probable that this great depression is also referable to the close of the Carboniferous period*.

To recapitulate in a few words—it appears, then, that immediately upon the close of the Carboniferous period the northern limits of the Lancashire and Yorkshire coal-fields were determined by the upheaval and denudation of the beds along east and west lines, while the coal-fields themselves remained in their original continuity across the region now formed of the Pennine hills from Skipton southwards, and that at the close of the Permian period these coal-fields were dissevered by the uprising of the area now formed of the Pennine range by lines of upheaval ranging from north to south, nearly at right angles to the former—this perpendicularity being of itself an evidence of difference of age.

* This great fracture has been traced by my colleagues of the Geological Survey of Scotland for many miles along the southern boundary of the coal-fields.

In the foregoing remarks I have assumed that the coal-fields of Lancashire and Yorkshire were originally united right across the area now occupied by the Millstone-grit and Yoredale rocks of the Pennine chain. That this was the case is abundantly proved by the similarity (approximating to identity) of the strata of the Millstone-grit series and lower Coal-measures on the opposite sides of the chain. This resemblance, and the identity of special coal-seams, has long since been pointed out by Professor Phillips, Mr. E. W. Binney, and Mr. Warington Smyth*.

System of North-west Faults.—Of later date, still, were those disturbances which resulted in the production of faults and fractures traversing the Lancashire coal-fields from N.N.W. to S.S.E., and dislocating the strata to an extent amounting, in some cases, to more than 1000 yards.

Some of these fractures can be traced into Permian and Upper Triassic strata—for example, the New Red Marl of the Cheshire plain.

As these fractures are of more recent date than the Trias, we must descend, in all probability, to the close of the Oolitic or Jurassic period before we can arrive at the time of their production; for there seems to be no break in the sequence of the Triassic and Jurassic formations after passing the line of discordance which marks the boundaries of the Keuper and Bunter divisions of the Trias.

We shall probably not err if we assign these fractures to disturbances which occurred at the close of the Jurassic age, at the same time admitting that they may have been modified at later times.

To sum up—it seems probable, then, that the main lines of disturbance may be assigned to three distinct periods:—

1st and earliest (Pendle system), E.N.E. direction, at the close of the Carboniferous period.

2nd, next (Pennine system), N. and S. direction (nearly), at the close of the Permian period.

3rd and latest (lines of fracture), N.N.W. direction, at the close of the Jurassic period.

These may also be expressed by means of a triangle, the sides of which are parallel to the direction of the forces (fig. 4).

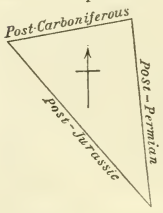


Fig. 4.—*Showing the relative ages and directions of the three principal systems of disturbance after the Carboniferous Period.*

* Introductory Address delivered to the Geological Section of the British Association, Newcastle, 1863, pp. 10, 11.

Periods of Denudation.

First Period.—Having shown, by the evidence of the unconformable patches of Permian beds on the northern flanks of the Pendle range agreeing with the position of the contemporaneous beds in Yorkshire, that the Pendle range had received its earliest outline at the commencement of the Permian period by the sweeping away of a prodigious amount of material to the north of the range, we cannot suppose that this was a solitary case. On the contrary, it is evident that the main features of the Carboniferous districts of North Lancashire and the North Riding were first shadowed forth at this same time.

This leads me to remark also that it is extremely improbable that productive Coal-measures exist under that tract of Triassic and drift-covered ground stretching inland from the coast to Ormskirk and Blackpool; for it can scarcely be doubted that the Carboniferous rocks under this tract were subjected to the same disturbances, and partook of a similar denudation to that which resulted in carrying away the Upper Carboniferous rocks from the vale of Clitheroe.

If, then, there was a period of disturbance throwing the rock-masses into a series of great folds, ranging from east to west across North Lancashire and Yorkshire, there was a corresponding and concurrent period of denudation, during which enormous masses of Carboniferous strata were swept away from these regions. These flexures died away southward, in which direction the corresponding amount of denudation was very much less, as is proved by the position of the Permian beds along the southern margin of the Lancashire coal-field. As the first movements of the Pennine system of flexures had not as yet commenced, we may suppose that whatever undulations may have been produced over the region now occupied by the high ranges of Black Hambledon, Blackstone Edge, Pule Hill, Kinder Scout, and the Derbyshire hills took an east and west direction, and were of minor importance in comparison with those which had been developed over North Lancashire and Yorkshire.

Second Period.—With the close of the Permian epoch commenced the movements which ultimately gave birth to the Pennine chain of hills, and which, by the denudation of the Upper Carboniferous rocks across the region of the central axis, caused the disseverance of the Lancashire and Cheshire coal-fields from those of Yorkshire and Derbyshire. To what extent these ranges of hills were subsequently entombed in Triassic strata is a speculative but interesting question. Recollecting the enormous vertical development of this formation in South Lancashire and Cheshire, amounting to nearly 4000 feet of strata, we may conclude that the Pennine and Pendle hills were encased in these red beds, and that to this protection they owe, to a certain extent, their preservation.

Third Period.—The third period of denudation was that which occurred after the Bunter Sandstone had been formed, and is represented

in Europe by the period of the Muschelkalk. The amount of material swept away in Lancashire at this period was probably not great; but of the fact itself there is the most positive evidence, as the basement-beds of the Keuper rest unconformably on an eroded surface of the Bunter Sandstone at Ormskirk, Liverpool, and Birkenhead.

Fourth Period.—The long ages of subsidence and submergence of the Red Marl, Lias, and the Jurassic groups elapsed, to the close of which, as it seems to me, we must refer the system of north-westerly faults which traverse the Carboniferous, Permian, and Triassic formations. Along with the production of these fractures, which displaced the strata to the extent of 3000 or 4000 feet in some places, there must have been a corresponding amount of carrying away of materials. The result of this, and probably of other more recent denudations, has been almost to obliterate all surface indications of these enormous vertical displacements, as in the case of the great Irwell-valley fault. In other cases, where the features of the ground do happen to indicate the lines of fracture, as in the case of the Up-Holland fault, it is only to the extent of a few hundred feet, while the displacement of the beds may amount to as many thousands.

Fifth Period.—The next period of denudation of which we have any evidence in this part of the country was that immediately antecedent to the period of the Lower Boulder-clay, or Till. In this instance there was probably a combination of ice-action, sea-action, and rain- and river-action, as the rocks at Liverpool, Horwich, Whalley, Clitheroe, &c. afford evidence of glaciation below the Boulder-clay. To this period many of the primary valleys and other features of the surface are to be referred.

Sixth Period.—The beds of sand and gravel which lie between the Lower and Upper Boulder-clays afford most clear evidence of extensive erosion and denudation before the deposition of the Upper Till upon them, as I have shown in my papers on the drift-deposits of Lancashire and Cheshire. To what extent this local erosion extended to the older formations it is impossible to say; but the effect was probably small. At the same time, in a summary of this kind, the occurrence of this period of denudation ought not to be passed over in silence.

Seventh Period.—The seventh and last period was that which ensued at the close of the Glacial epoch, and is still in existence. To this period is to be referred the channelling out of all the secondary valleys by "atmospheric denudation," and the modification by the same agency of all the physical features. Many of these valleys have been hollowed out in the lines of older valleys which had been partially filled in with drift-deposits, producing the phenomena of "valleys within valleys"*. No one, indeed, can traverse the hills of

* A term which I have employed to describe a class of physical features not uncommon in the Pennine chain, the Cotteswold Hills, and other districts. See my paper on "Modern Views of Denudation," in the 'Popular Science Review,' October 1866.

the Pennine and Pendle ranges, and witness the enormous landslips which have taken place in the districts of the Millstone-grit*, or the masses of rock and shingle brought down by the rivers when in flood, without being struck with the actual and possible effects of rain- and river-action; but when we come to compare these with the more ancient levellings of the surface between geologic epochs, the formation of successive planes of marine denudation, such as that of the Pennine chain as it was originally, and of the region of South Lancashire and Cheshire as it is now, I cannot but feel satisfied that the results of sea-action have been vastly more important than those of frost, rain, and rivers in sculpturing the surface of this part of England during successive geologic epochs.

* These are specially striking in the district of the Peak, Kinder Scout, and Derwent Edge.