Notes on the

Physical Geology of the Carboniferous Strata of Somersetshire, and associated formations.

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SOME ten years ago I had the honour of submitting to this Society, at the Shepton Mallet meeting, a short descriptive paper "On the Somersetshire Coal Field." I then endeavoured to lay before the Society a perpendicular section of the coal measures, and of their various subdivisions as they may probably exist in the centre of the Somersetshire basin, from the secondary rocks by which they are overlaid to the Mountain Limestone on which they rest. A longer residence in the district might now enable me to furnish similar information in a more complete form; but it is not my intention to go over old ground more than may be necessary to explain the present paper, the primary object of which is to point out certain remarkable facts in physical geology peculiar to the district in which the Society has met on the present occasion.

I. *Description of strata.*

In order at the outset to convey a general idea of the rocks with which we have to deal, I would direct your attention to a section of strata from Bath to Chewton Mendip, which, as it crosses the entire coal field from east to west, may be considered a typical section of the district generally.

You will observe it takes in a wide range geologically, from the Great Oolite in the neighbourhood of Bath, to the Old Red Sandstone, of which we find numerous outcrops in the centre of the Mendip range; and it would be difficult to select another district of country in which within so short a distance so many different formations may be closely studied. Whether

we examine the various materials of which those formations are composed, or the marvellous profusion of animal and vegetable life of which we find evidence in their fossil remains: whether we seek to investigate the conditions under which they were originally deposited, or the frequent changes to which they have since been subjected, we shall find here abundant material for scientific inquiry.

The section exhibits too what may be considered a distinctive feature in the geology of the district, viz., the number of secondary formations by which the coal measures are overlaid. The Oolite, Lias, Rhaetic, and New Red Sandstone have all been passed through frequently in the course of mining operations, and this circumstance has an important bearing on many other parts of England in which the absence of surface indications has hitherto prevented trials for coal. If we are to read one lesson more than another from the Somersetshire coal field it is this: that a covering of secondary rocks neither implies the absence of coal measures, nor their imperfect developement, nor even necessarily a very profound depth in searching for them, for beneath the Oolite, Lias, and New Red Sandstone of this neighbourhood, and within a limited depth, there exists a greater thickness of coal strata than is to be met with in most other parts of England.

The Somersetshire coal measures consist of several well marked divisions as shewn in the section. In descending order we find an upper division embracing the Radstock and Farrington groups of veins, then the Pennant, a mass of hard and comparatively unproductive sandstone; and beneath this the lower division, containing the New Rock and Vobster series of veins. The total thickness of coal strata, which cannot be less than 8,000 feet, rests upon the Millstone Grit and Mountain Limestone in the usual order.

Having given this brief sketch of the strata represented in the district I would now point out a few of their most marked physical features.

II. *The secondary rocks, conformable to each other, but not conformable with the coal measures beneath.*

On this branch of the subject probably other Members of this Society could convey more precise information than I possess, but without trespassing upon their special province, I may be permitted to say a word in passing.

There may be in the district under consideration some slight traces of unconformability in the relations of the secondary formations to each other, but an ordinary observer would probably fail to detect this for himself. When looked at in section, taking in a wide district of country, they present the appearance of being at least approximately conformable, and there is no evidence of any very marked break in the stratigraphical arrangement of any of the beds. There is perhaps most variation in the New Red Sandstone, which, in the centre of the Somersetshire coal field, consists of a considerable thickness of Keuper marl, with a thin bed of conglomerate at its base, while in proceeding southwards towards the Mendip the conglomerate greatly increases in thickness, and the rounded pebbles of which it is composed are of larger size, evidently indicating an approach to an old coast line of the Triassic sea.

Whatever may be said of the relations of the secondary rocks to each other, there is a very striking want of conformity between those beds and the older strata on which they rest. While the former are almost level, the latter, more particularly towards the edge of the basin, exhibit high and very variable angles of inclination, of which we shall presently have to speak, indicating an entire change of circumstances and probably a very wide break in point of time.

III. *The basin form of the coal measures.*

It will be seen by reference to the sections now produced that the coal measures of the district assume in all directions more or less of the basin form. In the section from east to west the strata form a perfect basin, the deepest point being in the

neighbourhood of Radford, from which the beds rise eastward towards Bath and westward towards the Mendips.

From north to south the same general outline is maintained, but the district has been divided into subordinate basins by transverse ridges which intersect the district. The most important of these is the great Kingswood anticlinal which crosses the entire coal field from east to west, forming a great natural division between the counties of Somerset and Gloucester. Another division line has been caused by the Farmborough fault which crosses the district from east to west, a little to the north of Camerton, Timsbury, High Littleton, and Clutton, separating the Somersetshire area into the basins of Pensford and Radstock.

With regard to this north and south section it is necessary to explain that while the Gloucestershire and Radstock portions are practically correct, considerable uncertainty exists as to the intermediate Pensford area which for many years has been little explored. The section shows one view which has been taken, but it is fairly open to controversy, and I am aware that Professor Prestwich entertains a different opinion. The prevailing idea locally is that the Farmborough fault to which I have referred is an upthrow north of 600 feet, throwing out the Radstock series in the district immediately to the north of the fault. This opinion has been founded on the result of a trial shaft sunk many years ago at Farmborough, which was supposed to have passed through traces of the Radstock series in the upper part of the pit, and then to have proved the Farrington group in an irregular and subdivided condition.

Professor Prestwich, however, is of opinion that the local view is inaccurate, and that more probably the Farmborough fault is a downthrow north, bringing in certain coal strata overlying the Radstock group.

Both opinions are fairly open to argument, but of this I have comparatively little doubt, that whether the Radstock series has been thrown out at Farmborough, as represented in the section,

or thrown down to a profound depth as suggested by Professor Prestwich, it reappears again in the vale of Pensford, although probably in a deteriorated form.

Having thus explained the general sectional structure of the district, I would now direct your attention to the geographical outline of the coal formation, which the diagram now shewn will explain more briefly and accurately than I could possibly do in words. You will observe that it leaves out those formations by which the coal measures have been overlaid, and that it endeavours to shew the different subdivisions of those measures together with the foundation rocks on which they rest, as they may have appeared before the earliest beds of the New Red Sandstone began to be deposited. Speaking generally the coal field extends from Cromhall on the north to the Mendips on the south, a distance of 26 miles, and from Bath on the east to Bristol on the west, a distance of 12 miles, to which we must add the outlying basin of Nailsea, the extent of which is rather uncertain. It embraces in all an area of 238 square miles, and in the report of the Royal Coal Commission it has been estimated to contain 6104 millions of tons of coal, a quantity amply sufficient to supply the wants of future generations.

IV. *The Mendip upheaval.*

It will at once be seen from the map and sections that the outline of the district we have been describing is largely due to the upheaval of the Mendip range on the south and west, and to certain other elevations of Mountain Limestone probably of similar age which form the margin of the coal basin further north.

The origin of the Mendip upheaval has given rise to much discussion. Some years ago, Mr. Moore having discovered in the neighbourhood of Stoke Lane the presence of an extensive basaltic dyke, originated the theory that the elevation of those hills was due to volcanic origin ; but by other authorities the Mendip range has been attributed to the effect of contraction

of the earth's crust. Whether the dyke referred to is to be regarded as the primary cause, or only a result of the Mendip upheaval,—whether it was the motive power which elevated some 20,000 feet of stratified rock into what must then have formed an elevated mountain range, or merely rushed in to fill a chasm produced by other forces, I must leave to higher authorities to decide. But whatever may be the true theory, much interest will ever attach to Mr. Moore's discovery, and we cannot fail to be impressed with the magnitude of the force, whatever its origin, which produced such marvellous physical results over a district of country extending from Frome to the Bristol Channel, and a continuation of which may be found on the Pembrokeshire coast.

Looking at the Mendips as we see them now, rising comparatively little above the level of the surrounding country, we can hardly realise the appearance they must have presented at the close of the coal measure period. From Weston to Frome, and probably far to the eastward, they must have attained an elevation outrivalling our highest mountain ranges, an elevation reaching far into the region of perpetual snow.

v. *Effect on the adjacent coal field; folded strata of the Vobster valley.*

Excepting the great thickness of strata upheaved, there is nothing very unusual in the structure of the Mendip Hills themselves. Between Weston and Emborow, it is true, there are subordinate to the principal range certain cross ridges, undulations, and contrary dips, which make the geology of that portion of the hills rather confusing, but from Ashwick to Frome their structure is of the simplest possible kind. They take the form of a true anticlinal, consisting of a central mass of Trap and Old Red Sandstone, from which the Mountain Limestone dips southwards towards Bruton and north-east towards Bath. It may be observed, however, that there is a marked difference in the angles of elevation on the two sides of the ridge, those on the north being so steep as in places to be almost perpen-

dicular, while those on the south side do not usually exceed 35 degrees, and this gentle inclination on the southern side deserves attention in connexion with mining prospects south of the Mendip. It is evident that the higher angles on the northern side have had a very remarkable effect upon the adjoining coal field, where we find evidence of by far the most striking phenomena connected with the Mendip upheaval. The area chiefly affected lies between Nettlebridge and Mells, where it is abundantly evident that during the Mendip upheaval the coal strata have not only been raised to a vertical position, but have actually been folded back upon themselves, so that instead of dipping northwards from the Mendip hills they now dip southwards towards that range. This extraordinary inversion of strata seems to begin at Nettlebridge, near the turnpike road from Bath to Shepton Mallet, for to the westward of that road the beds dip northward in conformity with the Mountain Limestone at an angle of from 30 to 40 degrees, but in proceeding eastward the dip gradually increases until the strata become perpendicular, and then fold completely over as shewn in the sections from Vobster to Radstock.

Between Pitcot, where the strata were discovered to be upright, and Mells new colliery, a distance of four miles, the country has been well proved by pits sunk at short distances apart, and there is no exception to the inversion of strata to which I have referred. How much farther eastwards it may continue it is difficult to say, but I am of opinion that it may be found to terminate not far to the east of Mells village. I arrive at this conclusion from a consideration of the angles of inclination prevailing in the Mendip hills. Between Binegar and Nettlebridge, where the dip of the Mountain Limestone does not usually exceed 30 to 40 degrees, the coal measures adjoining have a corresponding dip in the right direction, but between Nettlebridge and Mells, where we find in the limestone angles of 60 to 85 degrees, the adjacent coal measures have been uniformly inverted as already described; and as the angles of

inclination in the limestone eastward of Mells do not exceed from 30 to 50 degrees, I am led to the conclusion that in that direction the coal measures may gradually recover their natural position.

In all probability this abnormal dip may not continue to any very great depth. The lowest point at which it has yet been proved is at the Mackintosh pit, Newbury colliery, where, at a depth of 300 fathoms, the strata have been found dipping southwards at an angle of 45 degrees. How much farther this may continue we have no means of knowing, but there must be a point not far beneath where the strata resume the true northern inclination.

The strata in which the inversion is chiefly visible are the lower division of coal measures and the Pennant rock. It is not improbable that it may have extended to certain parts of the upper division, but so far this has not been proved. The effect of the fold is very different in the various beds. The Pennant rock and the upper part of the lower division have taken little harm from the disturbances to which they have been subjected: they are perfectly free from confusion although turned completely upside down; but the lower part of the division, which consists of very tender shales, has been twisted and contorted and broken up to an extent very difficult to realise.

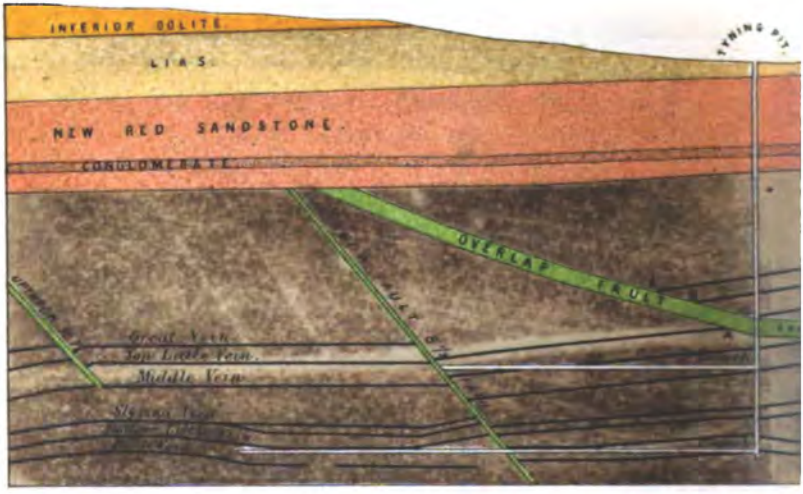
Associated with these up-turned coal measures and resting upon them there occur at Luckington and Vobster certain isolated masses of Mountain Limestone which must not be overlooked. As I hope shortly to communicate elsewhere my views on this part of the subject, I will only say in passing that these limestones must in some way have come over from the Mendips, and they may possibly furnish evidence of inversion in the denuded portions of the Mendip range, although we have no proof of it in the parts which remain.

VI. *The overlap or slide fault of Radstock.*

Another remarkable feature in the geology of the district is the occurrence at Radstock and its vicinity of the great overlap

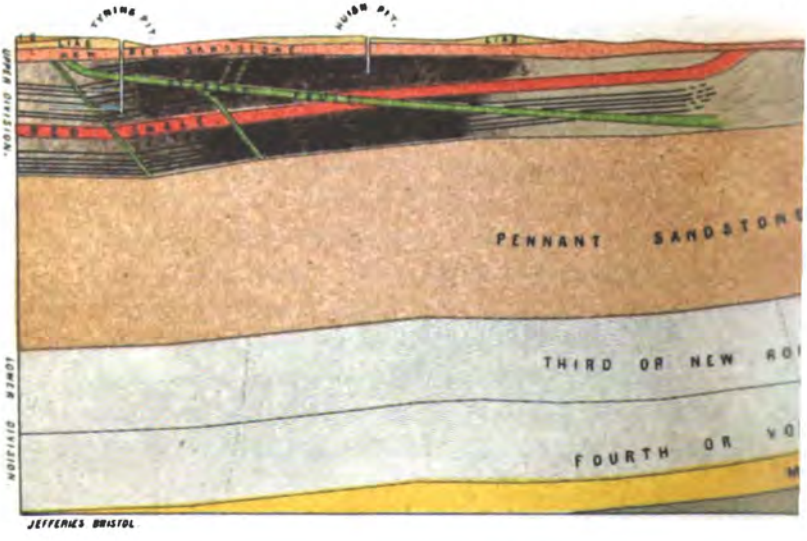
SECTION OF UPPER SERIES OF COAL

SCALE 40 FEET



SECTION OF STRATA FROM A POINT 616 YARDS

SCALE 4

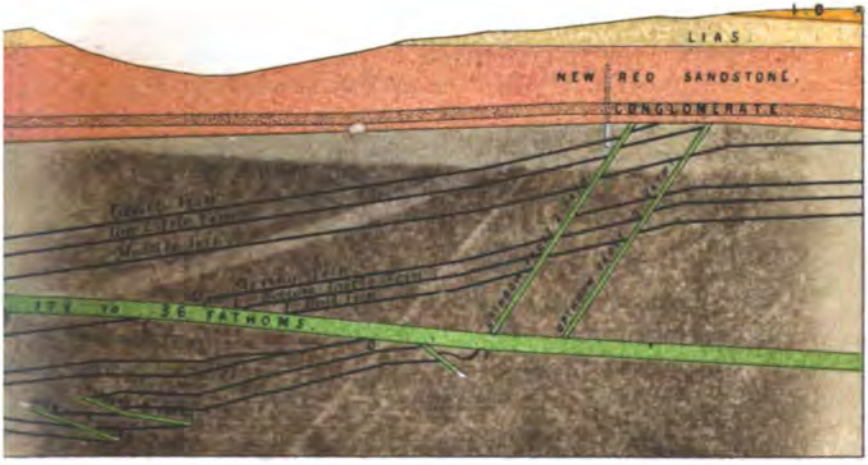


JEFFERIES BRISTOL

Nº 2.)

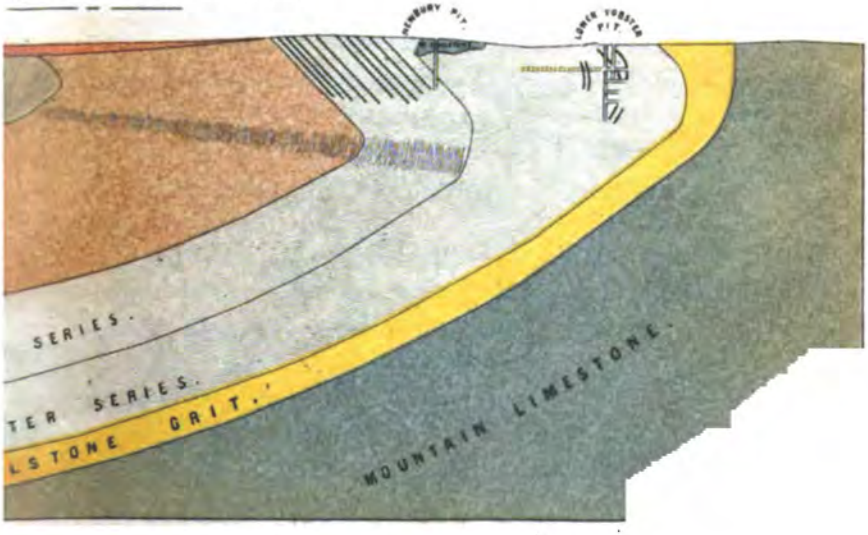
MEASURES UNDER RADSTOCK MANOR.

TO $\frac{1}{2}$ OF AN INCH.



NORTH OF TYNING PIT, RADSTOCK TO VOBSTER.

HAINS TO $\frac{1}{2}$ OF AN INCH.



or slide fault, which was discovered many years ago in working the Radstock series of veins.

The section of strata across the manor from north to south, passing through Tyning pit, shews the effect of the fault upon the upper group of veins. The strata above the line of fracture present every appearance of having been thrust bodily forward, so that the different veins now overlap each other as shown in the section, the letters *A A*, *B B*, &c., indicating those beds which were originally joined. The greatest extent of overlap hitherto proved occurs in the lower veins of the Radstock group and measures 330 yards, but the upper seams of the same series shew a much less amount of overlap, not exceeding 120 yards, from which an important inference may possibly be drawn.

The fault, which has been traced for more than a mile, shews a well defined line of fracture, the ends of the beds above it being turned slightly downwards, and those beneath having an upward curve where they are in contact with it, the leader or line of fracture consisting of crushed and broken coal measure materials of all kinds. The range of the fault is parallel with the Mendips, and although it has not hitherto been traced nearer to those hills than a distance of four miles, yet I have ventured to attribute its origin to the effect of that upheaval.

My views on the subject will be best explained by a section I have constructed from Vobster to Tyning pit, Radstock, shewing the almost vertical limestone on the northern slope of the Mendip hills and the folded coal measures adjoining, the lateral pressure produced by them having in my opinion caused the overlap fault.

There is to say the least of it a remarkable parallellism connected with the facts I have put before you. Where the dip in the Mendips is only 30 or 40 degrees, the adjacent coal measures have not been inverted, and in the interior of the basin we have no trace of the overlap fault; but where the Mendips shew angles of from 70° to 90°, we have exactly coincident with those steep dips, the overturned coal measures at the edge of the basin

and the overlap fault in the interior. This cannot I think be regarded as a mere coincidence, and it leads to the conclusion that the various phenomena I have been describing are only separate links in one great physical disturbance.

VII. *Denudation.*

Professor Ramsay long ago pointed out, and a very cursory examination of the sections now submitted and of the ordnance maps will be sufficient to shew, that between the close of the coal measure period, and the deposition of the New Red Sandstone, an enormous amount of denudation must have taken place. In the centre of the basin, where we find the conglomerate beds of the New Red resting on the higher beds of the coal measures, we have no means of measuring the amount of this denudation, and it cannot there have been so extensive, but in proceeding southwards and westwards we find the conglomerate resting unconformably on the upturned edges of the Pennant, the lower division of coal measures, the Mountain Limestone and even upon the Old Red Sandstone itself, shewing that in the Mendip country an enormous thickness of strata must have been washed away. The extent of this denudation we cannot measure accurately, but where (as in the district between Green Oare and Priddy) the Dolomitic Conglomerate rests directly upon the Old Red, the intermediate strata removed may be estimated as follows :—

	FEET.
Coal measures	8,000
Millstone Grit	500
Mountain Limestone .. .. say	4,000
	12,500
Old Red Sandstone, a portion only, say	3,500
Total	16,000

The effect of this denudation was to plane down a previously mountainous country to a comparatively level surface, on which the coal measures were afterwards deposited.

So far we have spoken only of the denudation prior to the secondary period, but even the secondary rocks in this district shew a considerable amount of denudation, the valleys which abound being with hardly an exception due to that cause.

VIII. *Remarks on areas outside the known coal field.*

So far we have been dealing with a district which has been carefully investigated and the principal facts of which have been well established, but it is surrounded on all sides by areas of which we know comparatively little, and which have long been the subject of curious speculation.

Sir Roderick Murchison, Mr. Godwin Austin, and Professor Prestwich have all devoted a good deal of attention to the question, and meeting as we do this evening just outside the margin of the known coal field, it may form a very proper subject of inquiry as to the unknown district which lies beyond.

Without expressing an opinion on the northern part of the field to which I have not devoted much attention, I think a great deal may be said about the district south and east of Frome. If we look at the great thickness of coal strata along the northern flank of the Mendips and the number of seams they contain we are impressed with the fact that we are probably far from the margin of that more extended basin in which the coal measures were originally deposited, and this impression is strengthened when we consider the geological structure of the Mendips. The anticlinal form of those hills leads at once to the inference that just as on their northern slope we find resting on the Mountain Limestone, the Millstone Grit, and the lower division of coal measures; so on their southern slope a similar state of things may probably exist, although hidden beneath a covering of secondary rocks.

And as to the district eastward of Frome, although the Mountain Limestone probably cuts off the coal measures in a line ranging from Frome towards Bath, many circumstances lead us to hope that they may not end there. The Mendips seem to form a link in an extended mountain chain stretch-

ing from Pembrokeshire through Frome towards France and Belgium, and on the north of this range the coal measures seem to occupy not one continuous area but many subordinate basins. In this country there are those of South Wales, the Forest of Dean, and Bristol, all divided by elevations of Mountain Limestone, and there may be other similar basins stretching across the South of England. On this subject, however, there is so much uncertainty, both as to the existence of coal measures, and (supposing them to exist) as to the depth at which they may lie, that explorations will be attended with much risk.