On the Probable Nature and Distribution of the Palæozoic Strata beneath the Secondary, etc., Rocks of the Southern Counties, with special reference to the prospects of obtaining Coal by boring South of the Mendips.

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INTRODUCTION.—So ably and so fully has the burning question as to the prospects of obtaining Coal beneath the Secondary rocks of the South of England been treated of in the Government Coal Commission Reports, and by Messrs. Judd, Prestwitch, and Whitaker, subsequently, in commenting on the supply of new facts, that any further remarks on the subject may appear to be redundant.

I think, however, that in transferring the question from a general to a local application, a more or less thorough acquaintance with any particular part of the area may be of use as introducing new factors for consideration, likely to be lost sight of or incidentally mentioned in a general review. When we consider that the south-western counties are, as it were, outside the range of the borings which have in recent years so much increased our knowledge of the underground Palæozoic rocks, and that they have in consequence received but little attention, it may not be amiss to offer some remarks on the general subject as bearing on this special region.

MAP I.

Tertiary and Quaternary.

Secondary Rocks.

Coal Measures.

Palæozoic Rocks other than Coal Measures.

Granite and Granitoid Rocks.

Geographical miles. *English miles.*

MAP SHEWING THE GENERAL DISTRIBUTION OF THE PRIMARY, SECONDARY AND TERTIARY ROCKS, AND OF THE COAL MEASURES OF ENGLAND AND WESTERN EUROPE,

—— BY W. A. E. USSHER. ——

MAP II.

GEOLOGICAL MAP

OF THE AREA BETWEEN THE QUANTOCKS AND MENDIPS,

BY W. A. E. USSHER.

As early as 1826, Buckland and Conybeare[1] pointed out the resemblance of the south-western Coal districts of England in geological structure and features to the country between Namur and Liège. Dufrénoy and Elie de Beaumont, in 1841,[2] inferred the extension of arms of the Carboniferous limestone sea from the Ardennes to the mountains of Wales and Scotland. M. Meugy, in 1852,[3] observed that "the considerable thickness of the Tertiary strata in the west of Belgium and the department of the Nord, shows that there is a great depression, which forms the subterranean foundation of the city of London; and if there exist coal basins, which is not impossible, these could advance toward the south border of this depression near to Lille, and be more or less directly connected with the vast Coal formation which crops up in England from Wales into Scotland."[4]

The following is the general purport of the report made by Mr. Prestwitch on the probabilities of finding Coal in the South of England.[5]

"About two centuries ago the Belgian coal field was found to extend beneath the newer formation on the frontiers into France as far as Valenciennes. An uninterrupted Chalk district extended northward, and the Coal measures were supposed to be lost. But at a later period valuable Coal was found to exist at Anjin. This led to further search, and the Coal measures have been gradually followed in a western direction, under the Chalk, to within thirty miles of Calais. Looking at these facts, and reasoning on theoretical considerations, Mr. Godwin Austen concluded that Coal measures might possibly extend beneath the south-eastern part of England. He showed that the Coal measures which thin out under the

[1] *Geol. Trans.*, vol. i, pl. 2, 2nd ser., p. 220.
[2] *Explication de la Carte Geologique de la France*, p. 724-5.
[3] *Essai de Geólogie Pratique sur la Flandre Francais*, p. 76.
[4] See also Warington Smith, *Coal and Coal Mining*, pp. 66 and 73; 1869.
[5] *Coal Commission Report*, vol. i, p. xii.

Chalk near Thérouanne probably set in again near Calais,[6] and are prolonged in the line of the Thames valley, parallel with the North Downs, and continuing thence under the valley of the Kennet, extend to the Bath and Bristol Coal area. He showed, upon theoretical grounds, that the Coal measures of a large portion of England, France, and Belgium were once continuous, and that the present Coal fields were merely fragments of the great original deposit preserved in hollows. These views are supported by many eminent geologists who gave evidence before the Commission, but they have been controverted by Sir Roderick Murchison, who contends that in consequence of the extension of the Silurian and Cambrian rocks beneath the Secondary strata of the South-East of England, and of the great amount of denudation which the Carboniferous rocks had undergone over the area of the South of England previous to the deposition of the Secondary formations, little coal could be expected to remain under the Cretaceous rocks. Upon a general review of the whole subject, Mr. Prestwich adopts, with slight variations, the views of Mr. Godwin Austen, and is led to the conclusion that there is the highest probability of a large area of productive Coal measures existing under the Secondary rocks of the South of England. He shows that the thickness of these overlying rocks is not likely to exceed 1,000 to 1,200 feet, and considers that there is reason to infer that the underground Coal basins may have a length of 150 miles, with a breadth of two to eight miles,—limits within which are confined the rich and valuable Coal measures of Belgium."

Professor Ramsay,[7] questioned as to the probability of Coal measures occurring under the Secondary rocks between the Mendips and Belgium, said:—"I should consider that the rocks below the Secondary rocks would lie in a series of

[6] See Appendix B.

[7] *Coal Commission Reports*, vol. ii, p. 423.

undulations, but whether any of those undulations would necessarily throw in basins of Coal measures I am not prepared to say."

"The basins which contain Coal measures are simply a few basins in hundreds of Palæozoic basins, some of which contain Coal measures, and some of which do not, and underneath the secondary rocks these basins lie in the same way that they do where other English Palæozoic rocks form the surface."

References to the Franco-Belgian and Westphalian Coal fields, and to their comparative productiveness in relation to the English Coal fields;[8] to the boring at Calais,[9] and to the Coals of the Boulonnais,[10] said to belong to the Carboniferous limestone, will be found in the Appendix.

Deep Borings.

An admirable resumé of the various deep trial borings bearing on the subject of the occurrence of Coal measures beneath the Secondary strata is given by Mr. Whitaker.[11] In briefly alluding to these, I shall group them according to proximity of latitude.

Harwich.—The most northerly of the borings in question was made at Harwich, on the Essex coast; in it Slaty Lower Carboniferous rocks[12] were encountered at a depth of 1,029 feet, being overlain by Gault.

Ware.—At about 56 miles west by south from this boring, a boring at Ware, in the adjacent county (Herts), proved Silurian rocks beneath Gault, at a depth of 797 feet.

Turnford, near Cheshunt.—At Turnford, near Cheshunt, in the same county, about seven miles south of Ware, Devonian rocks, consisting of Red Slaty Mudstones, were encountered beneath Gault at a depth of 1,081 feet.

Burford.—At Burford Signett, south of Burford, near the

[8] Appendix A. [9] Appendix B. [10] Appendix B.

[11] *Journal of the Society of Arts*, for April, 1890.

[12] See Appendix C.

western border of Oxfordshire, at about 68 miles due west of Ware, Coal measures were proved under Triassic and Jurassic (*i.e.*, Liassic and Oolitic) strata, at a depth of 1,180 feet.[13]

All the above are practically on the same latitude, there being only 15 minutes' difference between the most northerly at Harwich and the most southerly at Cheshunt.

London and Environs.—The borings in London and its environs may be grouped together; the most northerly borings, Meux's in Tottenham Court Road, and at Kentish Town, being about 12 to 13 miles south from Cheshunt; and the most southerly at Streatham, only about six miles further south.

In the Kentish town boring red and grey Clays and Sandstones, etc., of uncertain age, were encountered under Gault at a depth of 1,114 feet.

At Meux's Brewery, about two miles south of the Kentish Town boring,[14] Jurassic Limestones were encountered beneath the Gault, at a depth of 1,002 feet, and beneath them, at a depth of 1,064 feet from the surface, red shaly splitting mudstones, with an Upper Devonian Fauna, including *Rhynchonella cuboides, Spirifer disjunctus, Edmondia*, etc.[15]

At Crossness, near Blackwall, on the Thames, about 5½ miles eastward of Meux's, similar red beds to those in Kentish Town were met with beneath the Gault at a depth of 1,008 feet.

In the Richmond Boring,[16] about nine miles south-west from Kentish Town, similar red beds to those encountered at Kentish Town and Crossness were met with, at a depth of 1,239 feet, under 87½ feet of Jurassic (Great Oolite) clays

[13] Judd gives the thickness of Trias (Poikilitic) at Burford as 428 feet. *Quart. Journ. Geol. Soc.*, vol. xl, p. 753.

[14] See Appendix D.

[15] See Prestwich, *Q.J.G.S.*, Nov., 1878, pp. 902 to 913, where a full account of Meux's and the Crossness Borings are given. See also Whitaker's *Geology of London*, vol. ii, pp. 50—52.

[16] See Judd and Homersham, *Q.J.G.S.*, 1884, p. 724; and *Ibid.*, 1885, p. 523. Appendix E.

and limestones, overlain by Gault. These doubtful beds were proved to a depth of 208 feet.

In the Streatham Boring, 7½ miles south of Kentish Town, similar red and grey beds to those at Kentish Town, Crossness, and Richmond, were met with at a depth of 1,120 feet, under 38 feet of Lower Jurassic limestones, overlain by Gault.

The Chatham boring terminated in Oxford Clay, at a depth of 943 feet.

Dover.—The recent successful boring at Dover proved Coal measures at a depth of 1,160 feet, under about 660 feet of Jurassic (Portland to Bath Oolite) strata, overlain by Cretaceous rocks.

Battle.—The Subwealden boring near Battle was carried to a depth of 1,905 feet in Jurassic strata, proving a thick representation of the Upper and Middle Oolites.

Strike of Palæozoic rocks under London.—Mr. Whitaker points out the comparative evenness of the Old Rock floor beneath the Secondary strata, as shown by some of these borings. He considers that London is over one of the cross up rises, more or less at right angles to the main axis, probably separating Carboniferous basins.

Contour of the Palæozoic floor beneath the Secondary, etc., rocks of the South of England.—Whilst the heights above Ordnance datum of some of the borings, viz., Kentish Town, Meux's, Crossness, and Chatham, are given with the utmost exactitude by Prestwitch and Judd; others, as Battle and Burford, I could only ascertain approximately. To my colleague, Mr. H. B. Woodward, I am much indebted for obtaining information on this subject, and an error of 20 feet being of no consequence for my present purpose, the following heights may be taken as sufficiently accurate for all practical purposes, the figures underneath giving the actual depth from sea level of each boring, obtained by deducting the height above the sea from total depth to Palæozoic rock, or doubtful

red beds, or to Secondary rocks not penetrated, as the case may be :—

	Harwich.	Ware.	Burford.	Turnford (Cheshunt).	Meux.	Kentish Town.
Above Sea-level,	6	205	380	105	85.7 in.	186.6 in.
Below Sea-level,	1023	592	800	976	978.5 in.	927.6 in.

	Crossness.	Richmond.	Streatham.	Chatham.	Dover.	Battle.
Above Sea-level,	3.6 in.	17	110	16	say 5	245
Below Sea-level,	1004.6 in.	1222	1010	927	1155	1660

The practically identical level of the Devonian rocks in Meux's and the Turnford bores is remarkable; and the approximation to that level of the red beds in the intervening Kentish Town boring might be taken as some argument for the Palæozoic (Devonian or Old Red Sandstone) age of these red beds; whilst the fact that the Richmond boring, as shown by Judd, was carried to a depth of 208 feet in them, and therefore to a depth of 1430 feet below sea-level, might be said to point in the same direction; otherwise, regarding the red beds as Secondary, the Palæozoic floor would be at a lower level by over 450 feet at Richmond than at Meux's or Cheshunt, and by over 830 feet than at Ware. Leaving these red beds out of account for the present, the borings in which Palæozoic rocks were proved, exhibit an extreme difference in the level of the Old Rock floor between the shallowest at Ware and deepest at Dover of about 560 feet. The Dover Palæozoic level being over 350 feet lower than at Burford, and about 180 feet below the level of the Devonian at Turnford and Meux's.

On the other hand, on the most favourable assumption that

Palæozoic rocks might occur at 10 feet deeper than the termination of the Subwealden boring at Battle, their level would then be over 500 feet lower than at Dover, and about 1,080 deeper than at Ware.

The Battle boring was abandoned at a level 230 lower than that at Richmond, and at nearly 440 feet lower than the top of the doubtful red beds in that boring. If of Palæozoic age, the levels at which the doubtful red beds were encountered favour the comparative evenness of the Palæozoic floor; but, if of Secondary age, we should expect their depth at Richmond sufficient to warrant the belief in troughs or furrows in the Palæozoic floor, filled with coarse sediments, in the manner in which we find the Triassic Sands, Gravels, and Breccias of the Crediton and Tiverton valleys to have been accumulated in furrows or creeks worn in the Culm Measures. At any rate, whilst the comparative evenness of the Palæozoic floor, as deduced from a general comparison of the borings, points to the existence of an underground Palæozoic plateau, the Subwealden boring terminating in Oxford Clay, at a depth of 1,660 feet below sea-level (*i.e.*, over 500 feet deeper than the Coal Measures of Dover, and about 440 feet below the doubtful beds encountered at Richmond), is some evidence that the edge of the plateau lies to the north of Battle and to the south of Dover, probably on the north side of the 51st parallel. Following the supposed margin of the plateau westward, we find the elevation carried on in the Devonian highlands of Exmoor and the Quantocks. Of course one boring is rather slender evidence for such an hypothesis as this, but as it tends in the direction of caution, it is necessary to attach some weight to it.

On this hypothesis we might expect to find a gradually increasing depth to the Palæozoic floor proceeding from the supposed margin of the plateau (on the north side of the 51st parallel) southward. In the plateau area, on the contrary, we should expect local deepenings and ridgings, exhibiting,

perhaps, much greater discrepancies than that between the shallowest boring reaching the Palæozoic rocks and the deepest—that is, over 600 feet (between the Silurian at Ware and the doubtful beds at Richmond). But, taking these inequalities into account, there is, as it appears to me, no reason to conclude that the Palæozoic floor would anywhere exceed 2,000 feet in depth from the surface, and the probability of ridges occurring in an easterly direction from, or in line with, the Quantocks and Mendips, and in a southerly or south-easterly direction from, or in line with, the Lickey, Nuneaton, and Charwood Forest hills, seems very strong.

Cores from the London Borings.—The doubtful red and grey Sandstones and Clays encountered in the Kentish Town,[17] Crossness, Streatham, and Richmond borings, proved destitute of Organic remains. These materials, from the Richmond[18] boring, might pass for Triassic rocks. The buff Quartzose Sandstone, with fragmentary inclusions of red shale, is not altogether unlike certain very local varities of (Upper Keuper) Sandstone in the Keuper Marl of Somerset. The cores from the bottom of the Streatham boring, consisting of red and greenish or bluish-grey consolidated clay, are conglomeratic in places. On the other hand these rocks might be, as far as lithological character goes, assigned to the Old Red Sandstone, or even Culm Measures.

The uncertainty is enhanced by the probability that rocks obtained from such considerable depths below the surface, would present a very different aspect from the same rocks observed at their outcrop.

It is difficult to account for the occurrence of Old Red Sandstone surrounding a tract of true Devonian rock of such a type as that met with in Meux's boring. In Meux's and the Turnford borings, the Devonian consists of a purplish-red clay, with distinct cleavage or shaly structure; such a rock as the

[17] See Appendix D. [18] See Appendix E.

Goniatite Mudstones of Saltern Cove and Ivy Cove, near Paignton, in a much less broken and disturbed condition. But for the record of *Rhynchonella cuboides* in it, I should have referred it to the Fammenian or Upper part of the Upper Devonian, as the type resembles the Cypridinen Schiefer (Entomis Slates) of Goodrington and other South Devon localities, rather than to any of the North Devon rocks; and in South Devon the Cuboides beds are grey limestones below the Upper Devonian slates. In the vicinity of ridges of Silurian rocks, it is of course quite possible that the Upper Devonian might assume characters as abnormal as those of the rocks in the Kentish Town, etc., borings; but on the other hand, Keuper beds, exhibiting signs of marginal conditions, and enclosing small fragments of Red Devonian Clay Slates of the neighbourhood, seem to furnish a better explanation, as were the uncertain rocks a marginal type of the Upper Devonian, we should expect to find the Meux's boring cores to exhibit an arenaceous admixture, and a resemblance rather to the North than to the South Devon Upper Devonian.

Relations of the Devonshire Carboniferous Rocks.

As we proceed westward, along the 51st parallel of latitude, and approach the exposed Palæozoic areas of Somerset and Devon, the question of the existence of subterranean Coal fields is rendered more complex by considerations of a local character. These considerations involve the characters and relations of the Palæozoic rocks of Somerset, Devon, and Cornwall, which are of a more variable nature, and afford less definite evidence than those of Belgium and the north-east of France.

The Culm Type.—The principal factor in these local considerations is furnished by the assemblage of shales, Sandstones, and hard grits, which mainly constitute the Culm Measures[19]

[19] See Appendix F.

of Devonshire and North-east Cornwall, extending from Barnstaple, southward, to Tavistock and Ashburton. These strata contain no true Coal Measures; the carbonaceous plant markings, and the few anthracitic beds worked near Bideford (in producing the Bideford black), being altogether too insignificant to point to a correlation with the Coal Measures of neighbouring areas. As the prospects of Coal south of the Mendips were considered to depend on the easterly and northerly persistence of this Culm Measure type, it becomes most important to ascertain, as far as possible, to what horizons in the normal Carboniferous series of South Wales, East Somerset, and Bristol, it may correspond.

The Culm Measures (carbonaceous system of De la Beche) have, in a general way, been regarded as representative of the Carboniferous Limestone and Millstone Grit, the local occurrence of Limestone in the lower part of the series giving color to the former, and the prevalence of grits in higher parts of the series to the latter assumption.

It must be remembered that the Culm Measures are frilled, so to speak, by an innumerable series of small folds, insignificant in themselves, but most important in the reduplication of their constituent beds, so that no criterion as to their thickness can be formed by their extension to the north or south of the central axis of the main synclinal undulation. Sedgewick and Murchison were the first to point out the true position of the Culm Measures in a great trough. I have elsewhere[20] given a general grouping of the Culm Measures into three stages, at the same time pointing out, that although each group exhibited characteristics amply sufficient to justify the subdivison, yet the insensible transition of one type into another rendered anything like definite boundaries impossible. To this dictum there are, however, local exceptions in the lower beds of the formation, as we shall see.

[20] *Geol. Mag.*, 1886.

The Lower Culm Measures, as a whole, consist of irregular grey Shales or slaty Mudstones, with intercalated beds of hard, generally brown weathered, grit. The Slates or Shales are frequently splintery, as at Exeter, locally even, and blackish, as at Tresmarrow, near Launceston. They are associated with impersistent dark-blue Limestone, as at Lifton and elsewhere. It is seldom possible to trace, connectedly, the important, though variable, horizons met with in the Lower Culm Measures, owing to plications and faults, and perhaps also to impersistence. We therefore group these various horizons with the intercalated grits and shales which overlie them, in preference to assuming the persistence of a boundary locally well marked. Although both in North and South Devon, the exposed junctions of the Culm Measures and Upper Devonian are very rare, and anomalous appearances in the directions of dip are not seldom met with, yet there is no evidence of a discordance between the systems. In an unfaulted junction exposure near Dulverton, the transition from Culm to Devonian is scarcely perceptible. The same is the case in a junction exposure near Livaton, between Bickington and Bovey Tracey, in South Devon; and in the Tavistock country I have been unable to detect signs of discordance. Near Landue Hill, in the Tavistock and Callington country, De la Beche figures[21] a junction in which plicated Culm rocks have been over thrust on the Devonian Slates; without using the term thrust, he points out the forcing of the Culm Measures over the Devonian.

In the faulted district between Newton Abbot and Ipplepen, Culm Sandstones and Conglomerates at Rydonball Hill are succeeded by Upper Devonian beds; but here we are unable to say whether lower beds of the Culm Series are faulted out. The marked varities of the Lower Culm consist of cherty shales or Phtanites (the Coddon Hill beds of Professor Phillips).

[21] *Report on the Geology of Cornwall, Devon, and Somerset*, p. 107.

These beds occur in Tawstock Park, on Coddon and Hulverton Hills, etc., in North Devon, and in South Devon have been recognized near Chudleigh, on Ramshorn Down between Bickington and Bovey Tracey, near Lifton, Brent Tor, and Petherwin, in the Tavistock area. Even shaley stone beds, associated with buff or reddish shales, containing *Posidonomya Bechei*, *Goniatites spiralis*, and new species of *Phillipsia*, named by Dr. Woodward, *P. Leei*, *P. minor*, and *P. Cliffordi*, occur in Waddon Barton Lane, not far from Chudleigh, and throughout the Culm area, east of Chudleigh; also on the north of Tavistock,[22] and between Petherwin and Tavistock, the characteristic *G. spiralis* is also met with in even shales associated with the West Leigh (Burlescombe) limestones. *Posidonomya Bechei* occurs here and there, sometimes accompanied by impersistent Limestone bands, in the area between Chudleigh and Dunsford, where the normal Lower Culm type prevails. At the Lifton Limestone quarries, very dark shales, associated with irregular dark-grey Limestones, also yield *Posidonomya Bechei*, and these beds are, in the quarry, associated in the upper part with Phtanites or Coddon Hill beds. We have, therefore, a series of basement beds, containing marine fossils and distinctive local characteristics, which appear to give place to more ordinary types, and, *inter se*, to be intimately associated. In Ugbrooke Park, and the district east of Chudleigh generally, we find a distinct series of Sandstones, congolmeratic in places, overlying the *Goniatites spiralis* beds, and occasionally exhibiting plant markings. These beds appear to be a local developement, in this and the Newton Abbot country, of arenaceous conditions elsewhere displayed by the intercalation of grit bands in the Lower Culm shales. Whether the marked transition in Ugbrooke Park justifies the idea of a local unconformity, or not, between the marine and fresh-water types, elsewhere lost by gradually

[22] See *Trans. Dev. Assoc.* for 1889, pp. 437—451.

changing conditions, I think we are at liberty to assume that there is a much more marked change or distinction in the conditions attending the deposition of the Lower Culm rocks than in those between the Culm Measures and Devonian.

Foreign Correlations.—Turning to Belgium, in the environs of Dinant, on the Meuse, we find that the shales and Psammites, constituting the uppermost beds of the Devonian (Fammenien), are directly and conformably overlain by the Carboniferous Limestone, which has been subdivided by Dupont into six zonal groups, of which he furnishes an admirable description, illustrated by a map and sections.[23] The Upper Devonian type of this region is compared by Gosselet to that of the Pilton beds of North Devon and West Somerset. The evidence offered by Germany is equally satisfactory. On Von Dechen's map of the Rhine Provinces and Westphalia, we find the Upper Devonian described as Verneuiliischiefer, Kramenzel, and Flinz. The South Devon Upper Devonian type corresponds to this, the Verneuiliischiefer being represented by the Druid, Holne Bridge and Petherwin beds with *Spirifer Verneuili* in abundance, and the Kramenzel having an exact counterpart in the Goniatite Limestones of Chudleigh Petitor, etc. The Upper Devonian thus described is shown by Von Dechen to be overlain by Culm and Kohlenkalk.

In South Devon, as we have seen, the basement Culm Measures afford a representation of the *Posidonomya Becheï* horizon, which, however feeble, connects them with the Limestone developments of Swimbridge, Holcombe Rogus, and West Leigh.

Above the Culm and Kohlenkalk (or Carboniferous Limestone), Von Dechen places Flötzleerer (Sandstone), and above this the productive Coal Measures of the Coal field of the Ruhr (Westphalia).

In the irregular Sandstone developments in the Devon Culm

[23] Explication de la Fenille de Dinant *(Carte Geol. Belg.)*, 8vo., Brussels, 1883.

rocks, the futility of correlation by lithological character is sufficiently manifested, so that it is impossible to correlate Von Dechen's (Flötzleerer) Sandstones with any precise horizon in the Middle or Upper Culm Measures, in both of which Sandstones are abundantly developed. How far upward we should take the representation of the Carboniferous Limestone in the Devon Culm Measures is by no means clear. At any rate, we may infer that the Flötzleerer is homotaxeous with the Millstone Grit, and that that horizon is also represented by the Middle and perhaps also by the Upper Culm Measures of Devon.

The Upper Culm Measures, which occupy the centre of the Synclinal at about the latitude of Eggsford, may therefore, as far as the evidence goes, be either homotaxeous with the lower part of the Coal Measures, or the upper part of the Millstone Grit. If the former, the change of the horizon, prolonged beneath the Secondary area eastward, might well favour the occurrence of Lower Coal Measures; but if the latter, we should expect any reversion to the ordinary type to afford merely Carboniferous Limestone and Millstone Grit, and the chances of Coal to depend on the occurrence of troughs or basins deep enough to enfold strata higher in the series than the Upper Culm Measures. This consideration has a most important bearing on the subject, as there is not the least evidence to show that the Devonshire Culm Measures represent the normal Coal Measures, although they evidently constitute a local type, partly homotaxeous with the Carboniferous Limestone and Millstone Grit. Consequently it by no means follows that the persistent easterly prevalence of the Culm type precludes the chances of obtaining workable Coal Measures, which might well occur in basins supported by it beneath the Secondary rocks.

Signs of passage of Culm type into ordinary types.—Whilst the persistence of the Culm type by no means precludes the possibility of higher beds of productive Coal Measures being

troughed in the area concealed by the Secondary rocks, it is nevertheless of interest to notice what evidence we can find of the reversion of the Lower Culm Measures to the ordinary Carboniferous Limestone type. The greater development of Limestone on the borders of the Triassic area near Burlescombe may be taken as a possible indication of a gradual passage into Carboniferous Limestone at no great distance eastward. On the north the Carboniferous Limestone inlier of Cannington Park justifies the inference that a part, if not the whole, of the Lower Culm Measures has completely changed in character in a distance of about ten miles. This, coupled with the fact noticed by Kayser, of the arenaceous character prevalent to a more or less degree in all the Devonian subdivisions of North Devon, indicating a proximity to the Old Red Sandstone type, shows how very little reliance is to be placed on the permanence of local types in this area.

Carboniferous and Devonian.—From the correlation of the Lower Culm Measures with the Carboniferous Limestone, it follows that the Upper Devonian beds may be in part, at least equivalent to what is called the Lower Carboniferous Slate series of the South of Ireland; and if so, such correlations as the Pickwell Down beds with the Upper Old Red Sandstone are natural. Professor Hull, following Jukes' views, without falling into the error of endorsing his interpretation of the North Devon section, has ably advocated these correlations, but the admission of their truth would be no argument for the alteration of the Devonian nomenclature to suit local variations of its constituents. The Middle and Lower Carboniferous rocks are by no means typically persistent, whereas the Upper Devonian, if not more constant in type, is equally cosmical in distribution; so whilst the Lower Carboniferous Slates may be taken as a modification of part of the Upper Devonian type, it seems unphilosophical to abandon the name Upper Devonian in favour of a name which, if the correlation is distinctly proven, would be a misnomer.

Again, the retention of Old Red Sandstone is advisable as representing the lacustrine or estuarine conditions of the Devonian period; and as there must be areas in which the purely marine beds pass into the estuarine, in the absence of distinctive fossils, it is not desirable to abandon the term Upper Devonian as inclusive of any unfossiliferous sub-division which happens to resemble, or could even be proved to pass into, Upper Old Red Sandstone elsewhere.

As far as great Britain is concerned, the true connexions of the Old Red Sandstone beds with their marine Devonian equivalents have yet to be carefully worked out on the ground.

Strikes.

General Strike of the Palæozoic Rocks of England.—Looking at the Geological Map of England in a large way, we find that to the north of the Radstock and South Wales Coal fields, the longer axes of the Coal basins approximate more or less nearly to a north and south direction, whilst the South Wales and Radstock Coal fields trend in east and west directions, parallel to the general strike of the Palæozoic rocks of West Somerset, Devon, and Cornwall, and of the Mendips. The great contractile forces or shrinkage movements to which the Coal basins and saddles, or anticlinals, in the older rocks are due, whether wholly attributable to secular cooling, or in part to concurrent causes, are of the utmost importance in considering the Coal question, and have been largely treated of in the *Coal Commission Reports*, references to which will be found in the Appendix.[24]

Strike of the Palæozoic rocks of the South-Western Counties, and the connection of Granite with the movements producing it.—Although the Secondary strata often exhibit high dips, approaching the Palæozoic margin, and have received their easterly tilt from north and south movements, yet these have been insignificant in comparison to the great east and west

[24] Appendix G.

shrinkage lines of the Palæozoic strata of Devon, Cornwall, West Somerset, and the Mendips, produced long prior to the deposition of the Secondary rocks. The east and west strike is also in rough parallelism to the general distribution of the Granitic bosses of Devon and Cornwall.

In Normandy and Brittany, where great masses of Granite and Granitoid rocks occur,—notably between Alençon and Brest,—the general parallelism of the strike of the Palæozoic rocks to the east and west distribution of the Granites is still more apparent.

Geologists are agreed in assigning to the upheaval of the Devon and Cornish Granites, and to the production of the numerous Elvan dykes accompanying that upheaval, an age intermediate between the close of the Carboniferous and commencement of the Triassic epochs. Stated in this way, there is no room for difference of opinion, as the Culm Measures have been intensely plicated in pre-Triassic times, and that such plication should have accompanied the elevation of the Granitic areas is extremely probable. When, however, we are informed that the age of the Granite dates from its consolidation at a subsequent period to the deposition of the newest strata altered at or near contact with it, we may reasonably demur.

Against this doctrine of Granitic chronology, my friend, Mr. A. R. Hunt, has raised the standard of revolt on petrological grounds. The time-honoured dictum had for many years seemed to me to be inadequate to explain either the relations of the Granites to the stratified rocks, or the comparatively slight metamorphism of the latter, and I proposed for Dartmoor a laccolitic origin,[25] at the same time stating that such an origin could not be advanced if, as appeared probable, the Granite bosses of Dartmoor and Cornwall were protuberances of a subterranean connected mass. This probability seems too

[25] *Trans. Devon Assoc.* for 1888, pp. 141—157.

strong to be neglected, and apart from it I think the laccolite hypothesis, though much more reasonable than the accepted doctrine, affords a very partial explanation of the facts.

If we suppose great contractile forces, acting upon an area composed of Culm Measure, Devonian, and probably pre-Devonian strata, in various stages of consolidation, resting upon an uneven floor of hard, more or less, homogeneous rock, and mantling round its protuberances, it seems to me that we have an explanation of the relations of the stratified rocks to the Granite, of the alteration of the former at and near contact, and of the production of Elvan courses. This view also accords with De la Beche's observations in Cornwall, in which he maintains, with some exceptions ascribed to fault abutment, that the stratified rocks were turned up on the borders of the Granite.

On the hypothesis briefly set forth above, the metamorphism of the Granite, through partial re-heating, and of the stratified rocks near contact with it, would be ascribed to frictional heat, generated by great mechanical movements acting upon materials unequally consolidated. Whether these views will find acceptance, or have to be abandoned in the light of future research, certain it is that the vague explanations of Granite formation, now almost axiomatically accepted, are strangely inadequate to account for the phenomena they profess to explain.

This digression is not altogether out of place, as whatever views we may entertain as to the age and origin of Granite, there can be little doubt that the occurrence of the Granite in the Devon and Cornish area is a factor which must be taken into account in referring to the great shrinkage movements which gave their east and west strike to the Palæozoic rocks, whether the Granite existed in a solid condition long prior to these movements, or whether its protrusion accompanied them.

Similar Strikes in France, Belgium, and the Rhine Provinces.

—The east and west strike is carried on with more or less exactitude in the Devonian and Carboniferous areas of Belgium and North-eastern France, and the trend of the Saarbrück Coal field is parallel to the eastern termination of the Franco-Belgian, near Aix la Chapelle (Aachen), running in a north-easterly direction. Furthermore, in the Westphalian Coal field, the strike of the Devonian and Carboniferous rocks is in an east and west direction.

Importance of Strike in calculating the chances of reaching Coal basins beneath the newer rocks.—These considerations are of great importance in calculating the chances of obtaining Coal in any given area where Palæozoic rocks are not exposed, because borings in line with the strike would naturally give more prospects of success than across it, where the basins would be narrower.

To the north of the South Wales and Radstock Coal fields, as we have indicated, the general strike of the Palæozoic rocks changes from a more or less east and west, to a more or less north and south direction, and as the Bristol and Monmouth Coal fields rather exhibit the north and south trend, the line between the different directions of strike[26] is shown to be most irregular—so much so, that it is impossible to say what course it may take beneath the Secondary rocks and the evidence furnished by the borings, which have penetrated the Secondary strata, is quite worthless on this point, as the general strike of plicated Palæozoic rocks cannot be inferred from isolated observations, and still less from the small point of observation afforded by a boring.

For evidence of a persistent general strike, we cannot refer to a better case than the Devonshire Culm Measures, yet it would be manifestly absurd to assume that the observed persistence of this strike, for about 50 miles, is an argument for its prolongation beneath the Secondary rocks eastward, to a

[26] The change of strike takes place, roughly speaking, on a line drawn from Brecon to Frome.

point between Eastborne and Hastings, and thence across the Channel to the Franco-Belgian Coal field; although, as we have shown, the Dinant Upper Devonian type is allied to the Pilton beds of North Devon. The strike in the interval may vary considerably, and the Culm Measure synclinal may terminate at no very great distance eastward. Mr. Whitaker, in his admirable address, printed in the *Journal of the Society of Arts*, April, 1890, says:—"It should be noted that there is a sign, slight though it may be, of another possible line of underground Coal Measures starting on the east from the Saarbrück Coal field (S.W. of Mayence), and ending, perhaps, on the west, in the unprofitable Culm Measures of North Devon and Cornwall." The distance of the Saarbrück Coal field from the easternmost exposure of the Devonshire Culm Measures is about 470 miles; and whilst it is highly probable that the Carboniferous areas of Devon and Somerset were connected on the east with those of the Franco-Belgium area, and of Dusseldorf and Saarbrücken, it is hardly conceivable that any persistent synclinal connection of Carboniferous rocks now exists between these regions, although it is quite possible, as the passage quoted implies, that traces of such a connection might remain in isolated basins, but as Mr. Whitaker justly points out, the sites of underground basins can only be proved by experimental borings, and then there is always a chance of hitting on cross uprises. There is, as I have shown, absolutely no reason for supposing that the Devonshire Culm Measures represent the Coal Measures, and even if their uppermost beds belong to that division, it is extremely unlikely that they represent more than a part of the Lower Coal Measures, and it is very probable that we should find Coal Measures (probably the Upper) overlying them if the series were complete. In the passage cited, with reference to the Saarbrück Coal field, the correlation of the Culm Measures, with productive Coal Measures, is implied.

Coal Prospects South and South-East of the Mendips.

Prospects of Coal Measures in the area South of the Mendips.—We will now contract the scope of our remarks to the districts south-east and south of the Mendips.[27] As observed at the outset, the deep borings are too remote from this area to be of much service in direct application, they have however an indirect bearing, proving the extension of true Devonian rocks under London. As far as the persistence of the Culm type is concerned, they afford no evidence whatever, as the Dover Coal Measures might be based by strata of the Culm type, although the probability is in favour of the occurrence of Carboniferous Limestone. The only boring which has anything approaching a direct significance is that at Burford, in Oxfordshire, which penetrates Secondary strata of the same geological age as those we should expect to encounter in borings on the Oolite rocks, at such places as Bruton, Wincanton, Sherborne, and Bridport.

The abnormal thinning of the Secondary rocks in the Mendip area renders it exceedingly improbable that their thickness, in the Burford boring, would furnish any criterion as to the thickness likely to be encountered at any place in a similar geological situation on the south of the Mendips.

Triassic Rocks South of the Mendips.—We have, moreover, to make allowance for the fact, that the Triassic rocks, on the south of the Mendips, afford a more perfect succession than those of the Midlands, and below the Keuper, or Upper Trias, are not comparable with them. The Mendip range evidently separated the areas of deposit up to the Upper Keuper stage, although it is possible that a communication may have existed through a strait, further east, as early as the commencement of the Keuper period. The thickness of Oolitic, Liassic, and Triassic strata, from the surface to the

[27] See Appendix H.

Coal Measures, in the Burford boring, amounted to 1180 feet.[28] I calculate that the maximum thickness of the Trias, which is exhibited on the South Devon coast, certainly exceeds 3,000 feet; but its attenuation northward is very considerable, and the Lower beds are overlapped conformably by the Keuper on the Older rock margin, near Williton. The pre-Keuper beds do not appear, on the surface, in the Vale of Taunton, or between the Quantocks and the Mendips, and although they may be represented in hollows, in the Older Rock floor in this district, their thickness, as inferred from their northerly attenuation, would not be much more than 150 to 200 feet. It is only, however, to the south of Yeovil that we may regard the infra-Keuper beds as an important item, the insular condition of the Quantocks, and the inliers of Older Rocks in the Bridgwater Triassic districts, and also in the neighbourhood of Shepton Mallet, point to a deposition of the Keuper in a shoal area, studded by islands, which, except the Quantocks, were gradually submerged as the sediments encroached on the higher barrier slopes of the Mendips; it is not, therefore, likely that the districts between the Quantocks and the Mendips were under water in pre-Keuper times.

Areas, south of the Mendips, in which the probabilites of the occurrence of Coal basins are slight.—In treating of the prospects of obtaining Coal by borings through the Secondary rocks, it is obviously important to exclude from our consideration those parts of the district which would offer little or no chances of success. In this category I would include the Triassic area of West Somerset and Devon, on the west of the third meridian, west of Greenwich. From Taunton, southward, to Sidmouth and Seaton, we traverse a country crossing the direction of the strike of the Culm Measures, but that alone, as I have endeavoured to show in the foregoing notes, would not neces-

[28] For estimates of thickness of Secondary rocks in Wilts, Somerset, and Dorset, see Appendix J.

sarily prove an obstacle, as the Devon Culm type, in all probability, corresponds to lower horizons than the true Coal Measures; but the distribution of the Upper Culm Measures is rather in favour of the shallowing than of the deepening of the synclinal trough eastward, and therefore, against the probability of Coal Measures being troughed in, at any rate for a considerable distance, to the east of the exposed Culm Measure area. The probability of Coal Measures being troughed in may be greater or less to the east of the third meridian, according to the prolongation of the synclinal, and, as we have absolutely no grounds for inference, any opinion offered would be quite problematical. The north boundary of the Culm Measures, as far as it can be traced (a distance of forty miles), runs in a remarkably even line, trending east by south. If we are at liberty to assume the continuation of this strike eastward, it would cross the Channel from near Eastbourne, entering France at about ten miles south of Boulogne; but on this assumption we should have to go some distance further south to bore in search of Coal Measure basins, so that the chances would be limited to the south of a line extending from Tiverton to Portsmouth and Bognor, and could hardly be entertained to the west of Axminster.

Possibility of occurrence of Coal basins near the South Coast.—We have already pointed out the probability of the north-westerly strike of the Older Rocks of the Ardennes, from Bethune, toward the Boulogne Coal field, extending further to Dover, and thence across the floor of the London basin, toward the Coal fields of the Midlands. If we may reckon on a rough parallelism of strike over considerable distances, it is reasonable to suppose that the Culm boundary would exhibit a similar deflection, in which case the area of assumed Culm rocks, under the south of England, would be further restricted, and the chances of finding Coal proportionately lessened.

Independently of the chances of the Culm Measures reverting to the more ordinary Carboniferous Limestone type

in their easterly prolongation, the thickening or thinning of the whole, or parts, of the series might permit of the occurrence of Coal basins within a much more restricted space than where the series was developed. Experimental borings in such places as Dorchester, Lymington, and in the Isle of Wight, would no doubt go far toward solving these questions; but the depth of strata to be penetrated in these localities before reaching the Palæozoic floor would probably be not far short of 2,000 feet, and might be very much greater. In calculating this thickness, we assume that the Triassic strata of South Devon thin so rapidly on the Older Rock floor from their outcrop at Seaton and Axmouth eastward, as to be less than a third of their maximum thickness (*i.e.*, about a thousand feet) at Dorchester. But here again we pass into the realm of pure conjecture.

It is to be regretted that the borings near London were not carried to a sufficient depth to prove the age of the doubtful beds encountered in four of them; as if Triassic, we should not expect any considerable thickness of them before encountering Palæozoic rocks.

Probable Easterly Range of Devonian Rocks.—To the north of the line of direction of the northern boundary of the Culm Measures, assuming the synclinal structure of the latter, possibly with uprises of Devonian rocks, to be maintained, we should expect to encounter a prolongation eastward of the Devonian rocks of West Somerset and North Devon in a band about ten or twelve miles in width. Though, as in the case of the Culm Measures, local undulations, and the attenuation of the whole or parts of the Devonian might falsify our conclusions, it would be unwise to bore for coal, as a commercial speculation in the country beneath which we assume this band of Devonian strata to run, on the chance of incalculable possibilities occurring. Consequently we would not expect success to attend borings for Coal on the line of strike of the North Devon Devonian, which may be limited on the north

by a line drawn from Cannington across the Polden Hills to Salisbury, Winchester, and Hastings. That is, of course, on the assumption that this general strike is persistent eastward. To the north of this line there is no proof of the Culm Measure type occurring, the Limestone of Cannington Park in close proximity to Devonian, points, as we have said, to the passage of the Lower parts of the Culm into the Carboniferous Limestone type on the north of the Quantocks.

The Cannington Park Carboniferous Limestone is evidently faulted against the Devonian, and I am not in a position to say to what horizon the Devonian inliers of Cannington, Padnoller, Charlinch, and other places belong; whether they are Middle or Upper Devonian, or whether they have already assumed the Old Red Sandstone character,—so many years have elapsed since my survey of that area.

If the age of the Cannington, etc., inliers proved to be Upper Devonian or Upper Old Red Sandstone, it would have a most important bearing on the prospects of coal south of the Mendips, as the whole Devonian series might terminate in an anticlinal at a few miles east of the Quantocks, and in that case the passage of the Culm type into the Carboniferous Limestone type would take place in the area between the Polden Hills and Salisbury, and the chances of successful borings for Coal would be immeasurably increased, as, instead of occurring in a definite band, the Devonian rocks of North Devon would probably occur as a series of anticlinal inliers amongst Carboniferous rocks. Borings made between Salisbury and Yeovil would probably reach the Palæozoic rocks at depths of from 1,000 to 1,500 feet, and would go far to solve this important problem.

Mendip Area.—Mr. H. B. Woodward, in an address to the Geologists' Association (August 4th, 1890), says, "The general structure of the Mendip Hills is usually expressed in the term "Mendip Anticlinal." In reality the table-land is formed of a series of denuded anticlines, which trend in an

easterly and westerly direction, and thus do not coincide with the north-westerly and south-easterly direction of the range. There is evidence of at least five folds—the summits of which in four instances have been laid bare sufficiently to expose the Old Red Sandstone. As in the case of some of the remarkable folds in the Secondary rocks of the South and South-East of England, the strata on the northern sides of these anticlines usually plunge downwards much more steeply than on the southern side; and there are vertical strata and symptoms of slight overfoldings at one or two points on the northern side of the Mendip Hills (at Churchill Batch, and near East End, Leigh-upon-Mendip), as well as in the Steep Holmes, an islet in the Bristol Channel."

As a commentary on Professor Rucker's magnetic observations, Mr. Woodward observes that "Along the Mendip Hills, in the Old Red Sandstone, near Downhead, there is the dyke discovered by Mr. Moore, an eruptive rock that contains much magnetite; and yet within two miles productive Coal Measures are worked."

In allusion to the southern part of the Radstock Coal field, Mr. Woodward says, "The general structure of this portion of the Coal field has been justly compared with that of the Belgian Coal fields, where similar violent disturbances are met with, and where the qualities of the Coals are said to be similar. But it should be borne in mind that while Coal Measures have now been met with at Dover, we have no grounds for assuming that the possible underground tracts of Coal Measures between that locality and the Somersetshire Coal field occupy any more regular position among the folded Palæozoic rocks than do the known Coal basins in the western and midland areas."

The passage last quoted is excellent, in showing the futility of suggesting the continuation of continental Coal basins with English Coal fields.

Mr. Woodward further remarks, "The country to the south of the Mendip Hills, and more especially, perhaps, that near

Evercreech and Glastonbury, offers a favourable tract for speculative boring; for at present no one has ventured deep enough on this side of Mendip to prove the nature of the Palæozoic floor. There are, I believe, traces of Millstone Grit at one point south of Dinder, and again to the west of the Ebbor rocks; both localities being on the southern side of the range."

As Evercreech is in line with the northern boundary of the North Devon Devonian, and Glastonbury is very near it, the presumption of the general strike of the Devonian rocks being prolonged eastward must be taken into account in designating these places as suitable sites for experimental borings. It behoves us, therefore, to ascertain whether there are any local circumstances likely to counteract or modify this general strike sufficiently to admit of these places being possible sites for successful boring operations in search of Coal.

Disturbances in Northern parts of the West Somerset Devonian Area.—In the first place, we observe very much less regularity in the strike of the Devonian rocks in the districts of the Quantocks and to the north of the Brendon Hills, than further south. These signs of disturbance are especially noticeable in Croydon Hill and its vicinity, and in the Quantocks. The northern part of the Quantocks is composed of Hangman Grits, which I regard as representing the Upper Coblenzian or top of the Lower Devonian; from Bagborough northward these rocks seem to form an anticlinal, throwing off Middle Devonian, of which the whole of the southern part of the range is composed, on either side; this can be seen from the map accompanying my paper on the Triassic and Devonian rocks of West Somerset, in the *Proceedings* of this Society for 1889.

Nature of the Junction of the Devonian and Carboniferous at Cannington.—Now, if the junction of the Cannington Park Carboniferous Limestone with the Devonian were a natural one, the representation of the whole of the Middle and Upper

Devonian would have to be constricted to less than a third of the space these beds are always found to occupy in the North Devon and West Somerset area. Besides this, the Devonian inliers in the Triassic area between the Quantocks and Cannington Park usually exhibit the east and west strike, and in the absence of fossil evidence must be regarded as Middle or even in part Lower Devonian. There must therefore be either a great fault[29] between the Cannington Park Carboniferous Limestone and the Devonian, or a great unconformity. In either case the junction occurs not many yards south of the Carboniferous Limestone, and is concealed by Trias, which separates it from the long, narrow, east and west inlier of Devonian at Cannington. The Carboniferous Limestone resembles the small patch near Mells, on the Coal Measures, being evidently greatly disturbed, and dipping in a variety of directions, so as to preclude the possibility, almost, of natural superposition upon the Devonian. Unconformity alone would hardly account for this discordance, which must be ascribed to proximity to a pre-Triassic fault boundary. The magnitude of such a fault would be greatly reduced by the admission of considerable unconformity also existing between the Carboniferous and Devonian. There are no signs of unconformity between the Culm Measures and Devonian on the south, and in the Mendip area Mr. Woodward shows the complete passage of the Old Red Sandstone into the Carboniferous Limestone, through intercalation in the lower and upper parts of the intervening band of Lower Limestone Shales. His remarks are as follows:—"The oldest rocks of Mendip, the Old Red Sandstone, consist for the most part of red and brown micaceous Sandstone, with quartzose conglomerate, the latter disintegrated in places into a kind of gravel. No fossils, beyond obscure plant-like markings, have been recorded from the Old Red Sandstone of Mendip, but some fish remains have

[29] See Appendix I.

been found at Portishead, near Bristol. There is a gradual passage upwards from these rocks into the Lower Limestone Shales—well shown north of Black Down, in a gulley that leads towards Burrington Combe, and here the passage-beds yield Trilobites of the genus Phillipsia. These beds comprise alternations of Sandstone and Shale, merging upwards into the main mass of Shales, and these, higher up, contain bands of Limestone, and pass thus gradually into the Carboniferous Limestone. Both Lower Limestone Shales and Carboniferous Limestone yield many fossils, but at present the beds on Mendip have not been very carefully searched."

The mention of Phillipsia in the above suggests the correlation of the Lower Limestone Shales with the Waddon Barton beds, containing Phillipsia in the Lower or basement Culm Measures of South Devon.

From the above it will be seen that we have not a shred of evidence in favour of unconformity between the Cannington Park Carboniferous Limestone and the Devonian. Therefore the fault[30] must be of sufficient magnitude to cut out a considerable part of the Devonian series. As it is not exposed we can only conjecture as to the nature of this dislocation, which might be a thrust plane; at all events its direction would appear to be towards East Quantockshead, and from thence beneath the Bristol Channel, not far from the West Somerset and North Devon coast line. The great fault at Oare is probably an off-shoot of this great dislocation, and the disturbances of the Devonian rocks of Croydon Hill and the north part of the Quantocks may be partly occasioned by it. It will be at once apparent that the easterly prolongation of this dislocation may have a most important bearing on the prospects of the occurrence of Coal south of the Mendips.

Probable Direction of the Cannington Fault Eastward.—The direction of an unseen fault[31] can scarcely be traced by such

[30] See Appendix I.

[31] See Map II.

slight evidence with any degree of certainty, so it is safer to allow a margin for error. In supposing its course to run slightly across the general strike direction of the Devonian rocks on the south of the Polden Hills, and Castle Cary, towards Wincanton, we must allow for a more northerly prolongation, as the assumed direction from East Quantockshead to Cannington Park must be deflected from Cannington Park in a nearly due east direction, on account of the Devonian inliers. If this deflection is only temporary, say for two or three miles, and the former line is resumed, it would run by Stawell and Butleigh to Wincanton; but if, on the contrary, the easterly deflection continues, the underground fault would cross the Poldens at Cossington and Chilton, and leaving Glastonbury and Pennard Hill on the south, would run through Pilton to Witham, Evercreech being more than a mile to the south of this line.

These considerations are purely hypothetical, yet from the nature of the case they must be entertained.

The best Sites for Experimental Borings to prove the Distribution of the Devonian and Carboniferous rocks, considered.—The question of most importance is the easterly extension of the Devonian rocks. This could only be proved by experimental boring at such places as Compton Dundon, East Lydford, Lovington, North Barrow, Yarlington, or Wincanton. If we suppose a boring at Compton Dundon to prove Upper Devonian strata, and a boring at, say, North Barrow to prove Carboniferous, either of Culm or Carboniferous Limestone type, we might reasonably conjecture that the North Devon Devonian terminates in an anticlinal somewhere about Charlton Adam or Babcary, and that to the east of these places Coal Measures might be troughed in in the synclinals and Devonian rocks rucked up in anticlinals. The positions of favourable sites for Coal borings could only be ascertained by experiment, and probably only then after repeated failures, each of which would furnish additional evidence for future guidance, always

assuming that the trial bores reached the Palæozoic rocks.

If Middle Devonian occured at Compton Dundon, unless there were a great fault in the intervening district, it would give a very unfavourable aspect to the chances of the occurrence of Coal Measures under Glastonbury. Again, if trial borings proved Devonian rocks at North Barrow, Castly Cary, or Wincanton, they would favour the continuation eastward of the North Devon Devonian rocks on their general strike, and so preclude the probability of obtaining coal over a considerable area.

We could hardly expect to obtain evidence of the position of the Cannington fault if prolonged by trial borings, as Devonian rocks might anywhere occur on the north and Carboniferous on the south side of it. If the fault in question were a thrust plane, the chances of proving it by boring would be increased, but the conjecture leaves the question as to the easterly continuation of the Devonian rocks untouched.

Trial borings at Street, East Pennard, Evercreech, or other places in the same country, would no doubt throw a flood of light on the underground structure, and might prove Coal Measures, but we should not recommend, for the reasons stated in this paper, any direct attempts to obtain Coal being made to the south of a line between Cannington and Witham. Experimental borings, particularly in such sites as we have indicated, would be of the greatest scientific interest, and indirectly of much practical value. Having in the foregoing pages narrowed the question, to a very small compass, we will briefly consider the district least open to the objections put forward.

District most favourable for Boring operations in search of Coal.—The district on the north of a line drawn from East Quantockshead to Witham appears to be the most promising for obtaining Coal beneath the Secondary rocks.

Mr. Woodward, in one of the passages quoted above, points out the gentler inclination of the rocks on the south of the

Mendip anticlinals. Bearing this in mind, it is obviously unadvisable to put down borings in proximity to the Older rocks, exposed on the south slopes of the Mendips, and of their prolongation in Bleadon Hill, Uphill, and Brean Down. The prolongation of the Carboniferous Limestone by plications from the exposed margin southward, is proved by its presence in inliers amongst the Secondary rocks near Shepton Mallet, Draycot, etc. The occurrence of an anticlinal of Old Red Sandstone at Wells would render borings for some distance west in line with its strike unprofitable. The most probable location of an underground Coal basin in this area would be enclosed by an irregular line drawn from the coast near Otterhampton, through Pawlet, and Meare, to Polsham; from Polsham to Wedmore, and thence by Badgeworth and Lympsham to the Channel coast at Brean.

Best Sites for Boring.—Within this line the best sites for trial borings would be in the vicinity of Highbridge, Burnham, and Berrow; at East or South Brent, Chapel Allerton, Wedmore, Meare, and Mark. The depth of strata likely to cover the Palæozoic floor at these places might be expected to vary from four or five hundred to a thousand feet, but it is improbable that it would anywhere exceed a thousand feet.

The boring near Compton Dundon, abandoned in Keuper Marls at a depth of 609 feet, affords no criterion of the thickness of the Keuper, which may very well amount to a thousand feet at Compton Dundon, decreasing northward with the gradual uprise of the Palæozoic floor approaching the Mendips.

Disturbances, etc.—There are no doubt many undulations and faults in the Carboniferous beds south of the Mendips. To the former we owe the appearance of the Carboniferous Limestone inliers on the south of Dinder, between Shepton Mallet and Wells, and those of Lodge Hill and Decoy Nyland, and near the hamlet of Wookey; these last mentioned neutralizing any favourable impressions that might be sug-

gested by the appearance of Millstone Grit near Ebbor Rocks. From the occurrence of faults affecting the Old Red and Lower Carboniferous beds near Wells, Westbury, and Cheddar, it is very probable that similar beds may be thus affected beneath the Secondary strata, nor should we be surprised to find reversed faultings and thrusts.

The actual occurrence of such disturbances is proved by a well known case:—"The remarkable slide fault which has thrust almost horizontally the upper portion of the Radstock series over the lower half, back from the direction of the Mendips northward, for a distance of from 130 to 220 feet, extending beneath Radstock from the 'Old Red' in the north to an unknown distance southwards (but certainly past Bramhill Farm), and from Upper Writhlington Pit in the east, probably to the village of Welton in the west. The vertical displacement caused by this fault varies from 0 to 60 yards, and the amount of slide from 0 to 350 yards."[32]

Professor Prestwich[33] gives sections of borings at Auchy au Bois, in the Franco-Belgian area, showing reversed strata of Devonian and Carboniferous age overthrust upon Coal Measures. These, and the Vobster phenomena, show how uncertain are the relations of soft and easily compressible strata, such as the Coal Measures, to the more unyielding masses of Grit and Limestone in highly disturbed areas.

The anomalous positions of the three patches of Carboniferous Limestone at Luckington and Higher and Lower Vobster have attracted much attention, Messrs. McMurtrie[34] and H. B. Woodward[35] having endeavoured by different methods to account for the phenomena, and Mr. Winwood[36] has lately brought to light some new facts about Upper Vobster.

[32] *Coal Commission Report*, vol. i, pp. 40 and 62.
[33] *Quart. Jour. Geol. Soc.* for 1878, pp. 905, etc.
[34] *Proc. Bath Nat. Hist. and Antiq. Field Club*, 1876, vol. iii, p. 287.
[35] *Geol. Mag.*, April, 1871, and October, 1876.
[36] *Proc. Bath Nat. Hist. Club*, vol. v, p. 24.

Mr. McMurtrie's explanation does not appear to concord with the normal anticlinal structure of the Mendips on the south, there being no reason to suppose that the apex of the anticline, before denudation, was inverted northward, so as to favour the subsidence by denudation and slip of masses of Carboniferous Limestone over Coal Measures.

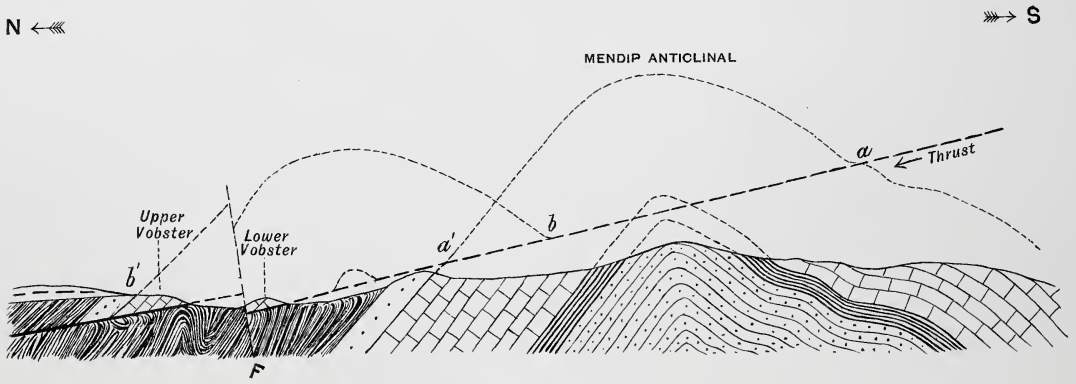
Mr. Woodward's diagram, although not open to the same objection, seemed to me rather more complicated than was absolutely necessary, so I endeavoured to explain the phenomena by a thrust plane, as shown in the accompanying sketch, the Limestone anticlinal being supposed to be shifted from *a*, *a'* to *b*, *b'*; and the smaller much disturbed Limestone mass of Lower Vobster to owe its position to a fault hading north. I would also suggest that the prevalent northerly dips in the Coal Measures might be due to reversal in proximity to the sole of the supposed thrust. This idea, brought before the British Association in 1888, seemed to me too crude to deserve special publication, and it is only given here incidentally in answer to the challenge of my friend Mr. Woodward[37] as a matter of local interest; the data are insufficient to furnish anything more than a general explanation.

Conclusion.

By a comparison of the relations of the Culm Measures and Devonian with similar rocks in the Dusseldorf area, and with the relations of the Carboniferous Limestone and Upper Devonian of the Franco-Belgian area, we have shown that the easterly persistence of the Culm Measures in the southern counties may not necessarily preclude the occurrence of Coal basins troughed in, in the manner we find them troughed in the Coal basins where the ordinary Carboniferous Limestone and Millstone Grit types occur.

Owing to the absence of signs of deepening in the Culm

[37] See *Brief Notes on the Geology of the Mendip Hills*, by H. B. Woodward, printed for the Geologist's Association, 64, High Street, Lewes, 1890.



HYPOTHETICAL SECTION TO EXPLAIN THE SUPERPOSITION OF CARBONIFEROUS LIMESTONE UPON THE COAL-MEASURES AT VOBSTER, &c.

Inferior Oolite — *Coal Measures* — *Millstone Grit* — *Carboniferous Limestone*

Lower Limestone Shale — *Old Red Sandstone*

Measure synclinal, from west to east, we would restrict the probabilities of the occurrence of underground Coal basins in the Culm Measures, to the area east of Axmouth and Seaton, and south of a line drawn from Tiverton to Portsmouth. Owing to the probability of the Devonian Rocks being prolonged eastwards, in line with their general strike, and to the very doubtful easterly direction of a great fault, separating the Carboniferous Limestone from the Devonian, on the south side of Cannington Park, the prospects of the occurrence of Coal basins, to the south of a line drawn from East Quantockshead to Witham, are too dubious to justify direct borings in search of Coal. The aspect of the case would, however, be entirely altered if experimental borings, in the country between Compton Dundon and Wincanton, proved the termination of the Devonian rocks in an anticline in the Carboniferous rocks, as then the occurrence of Devonian rocks, and Coal basins, would depend on the denudation of anticlines through the Carboniferous in the former respect, and on the occurrence of synclines, sufficiently deep to trough in Coal Measures, in the latter.

The probable limits of an underground Coal basin, between the Quantocks and Mendips, seemed to be roughly defined by a line drawn from the coast, near Otterhampton, to Polsham, eastward, and from Polsham, westward, by Wedmore and Badgeworth, to the coast at Brean. Within these limits borings are to be recommended at such places as Berrow, Burnham, Highbridge, Meare, Mark, and Chapel Allerton. It is improbable that the depth to be penetrated before reaching the Palæozoic strata would exceed 1,000 feet in any of these places, whilst the irregularity of the Old rock surface, and its uprise toward the Mendips, might be expected to reduce the depth to 400 feet or less, proceeding northward.

The greater depth of Secondary strata proved in the Subwealden boring tends to indicate the existence of a subterranean Palæozoic plateau, terminating somewhere along a line of latitude between Dover and Hastings, and to the south

of this line we should expect to find the depth of the Palæozoic floor to increase toward the South coast.

The prevalent east and west strike of the Palæozoic rocks of the South-Western Counties and South Wales Coal basin gives place to a more or less north and south strike on the north of Radstock, exemplified in the Bristol and Monmouth Coal fields, and maintained more or less throughout the Midland and Northern Counties.

It is a question of considerable importance whether the north and south strike of the Bristol Coal field continues eastward in the Palæozoic floor of the London basin, or whether the east and west strike of the Mendips prevails towards Dover. The Silurian ridge at Ware occurs in a locality more or less in line of direction with the trend of the Lickey Quartzite ridge, and the inliers of Nuneaton and Charwood Forest, there being an apparent tendency to a south-east or south-south-east trend in the direction of London. On the other hand, the general east and west trend of the Palæozoic rocks of the Ardennes manifests a tendency to assume a north-westerly direction between Bethune and the Coal fields of the Boulonnais, and if we admit the probability that this direction is continued to Dover, it seems rather more probable to continue it in a similar direction across the London basin to the Coal fields of the Midlands, than to suppose a westerly deflection from Dover toward the Mendips.[38]

In any case, a northerly or north-westerly general strike of the Palæozoic rocks under London and its environs seems more probable than an east and west strike.

[38] The resumption of the east and west strike in the Westphalian Coal field, after its north-easterly deflection from Aix la Chapelle, may however be fairly cited in favour of a similar assumption from Dover westward.

APPENDIX A.

From the Coal Commission Reports.

Vol. i, p. 151. Prestwich's Report.—The following is the succession of the great Coal fields which extend on or about the same line of strike from Westphalia to N.E. France:—The easternmost, that of the Ruhr; the second, that of Aix la Chapelle; the third, the Liége Coal field, 45 miles long by from 3 to 8 miles broad; the fourth, Coal field of Charleroi, Mons, and Valenciennes, 65 miles long by from 2 to 8 miles in breadth. In all these the Coal Measures are tilted up or faulted against Carboniferous Limestone and Older Rocks.

Vol. ii, p. 426. Mr. Godwin Austen's examination. The Westphalian, or Coal field of the Ruhr, is very productive. "It has an enormous thickness of the Millstone Grit series of English geologists at the base of it, and this overlies the true Mountain Limestone," a great band of which forms the basin of the Coal series. This Coal field "is very much disturbed on its western margin." It has been proved by borings to have a great northerly extension under the Cretaceous. "The correspondence is perfect between the Aix la Chapelle and the Ruhr bands."

Vol. i, p. 154.—The mean thickness of the Coal Measures in the English and Franco-Belgian Coal fields is given as follows in Mr. Prestwich's Report, the estimates for Lancashire, Warwickshire, Derbyshire, Durham, and Leicestershire being Professor Hull's:—

South Wales.	Somerset.	Hainaut.	Liége.	Westphalia	Lancashire	Warwickshire.	Derbyshire	Leicestershire.	Durham.
Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
11,000	8,400	9,400	7,600	7,218	7,000	3,000	2,600	2,500	2,030

The Pennant rock, 2,000 to 3,000 feet in the English Measures, "is replaced by productive measures in Belgium," hence the greater amount of workable Coal in the foreign Coal fields, as shown in the following table:—

	S. Wales.	Somerset.	Hainaut.	Liége.	Westphalia.
Number of Seams ..	75	55	110	85	117
Total thickness of workable Coal	120 ft.	98 ft.	230 ft.	?212 ft.	294 ft.

APPENDIX B.

From the Coal Commission Reports.

Vol. i, p. 153. Prestwich's Report. Section of Boring at Calais:—

	Feet.
Sands and Gravel	80
Tertiary	161
Cretaceous	791
Carboniferous—Shales, Sandstones, and Limestones ...	106
	1138

Vol. ii, p. 437.—Murchison said that the Calais Carboniferous belonged to the Millstone Grit series, which in England and Wales never contains Coal, and cannot there be said to constitute a Coal field.

Vol. i, p. 157.—Prestwich, on the contrary, believed them to have been originally connected with "the lower and more unproductive beds" of the Franco-Belgian Coal fields.

Vol. ii, pp. 429, 430. Godwin Austen.—Coal in the Boulonnais, about five miles from the coast, probably containing only five workable seams. The strike is north-west by west, or, on an average, west-north-west.

Vol. i, p. 157. Prestwich's Report.—The Hardinghen Coal field "was at first supposed to be a prolongation of the true Coal Measures of Belgium, but it is now considered to be of older date and to underlie them. The Mountain Limestone of Belgium contains an intercalated group of strata, with a few poor seams of coal, none of which are, we believe, worked. Mr. Godwin Austen has shown that the Hardinghen Coal Measures belong to this group, and that 'the Coal of the Boulonnais is not at all the Coal of the (great) Belgian band,' which band he has 'conjecturally represented as extending west of Calais.' These Hardinghen Coals are nevertheless of the same age as some of the coals more profitably worked in the Mountain Limestone of Scotland and the North of England. The Carboniferous Limestone, with these associated Coal beds of the Boulogne district, passes probably under the Wealden area. In Somerset, where this Limestone again

comes to the surface, no traces of these subordinate beds are found. On the two grounds, therefore—that the Hardinghen Coal field is extremely poor, and that it thins out westward—there seems to us but little chance of meeting with productive Coal Measures under the Wealden area . . . . we perfectly agree with Sir R. Murchison."

Footnote.—"At the same time, as the Hardinghen Coal Measures are the result of local expansion of still poorer beds in Belgium, whether that expansion may be maintained or may even increase for a time in the range westward admits of a question."

APPENDIX C.

HARWICH BORING. CARBONIFEROUS ROCKS.

From the Coal Commission Reports.

Prestwich's Report, vol. i, pp. 149, 150, and 162.—Harwich boring reached dark slaty rock containing Posidonomya, at a depth of 1026 feet, which was bored into for 44 feet. "In the Mons district (similar dark compact slaty rock, with Posidonomya) attains a thickness of about 200 feet, reposing on the Carboniferous Limestone, and immediately underlying the Coal Measures." "Posidonomya is found in the Carboniferous Limestone of Devonshire and of Belgium."

Vol. ii, p. 435.—Murchison remarked that Posidonomya was well known to occur in the lowest beds of the Mountain Limestone on the coast of Northumberland.

Vol. ii, p. 493.—Professor J. Phillips considered that the Harwich cores corresponded with the lower part of the Carboniferous series of North Devon.

Vol. ii, pp. 432, 433.—Godwin Austen referred the Harwich rocks to the Posidonomyen Schiefer of Westphalia, above the Mountain Limestone, and at the base of the true Carboniferous series; he said that "in Devonshire a great deal of the roofing slate is from the Posidonomyen Schiefer, and is about the equivalent of the Mountain Limestone." See also vol. ii, p. 513.

APPENDIX D.

KENTISH TOWN BORING. DOUBTFUL ROCKS.

From the Coal Commission Reports.

Prestwich's Report, vol. i, pp. 149 and 162.—Kentish Town boring, made in 1854-5. Surface, 180 feet above sea level; 1,302 feet penetrated, 188 of which Red and Grey Sandstones reckoned as Palæozoic, and said to be indistinguishable from the Old Red Sandstone of the neighbourhood of Frome.

Vol. ii, pp. 432, 433.—Godwin Austen considered the Kentish Town Sandstones and Quartz Pebble beds as the base of the Cretaceous (*i.e.*, equivalent to Tourtia), not Trias, because that formation is wanting in North Belgium.

APPENDIX E.

Judd, "On the Nature and Relations of the Jurassic Deposits which underlie London, etc.," *Q.J.G.S.*, vol. xl, p. 732. "Richmond appears to be situated on the downthrow side of the series of faults which traverse the London basin from east to west."

P. 740.—The 10 feet of Neocomian in the Richmond boring is in nature and relations analogous with the Belgian Tourtia; it is largely derived from the subjacent Great Oolite.

P. 760.—Anthracite fragments and pebbles of Coal Measure Sandstone occur in the junction beds above and below the Great Oolite at Richmond proving that Coal Measures with Anthracite seams were among the rocks of the Old Palæozoic ridge.

P. 755.—The Great Oolite probably never extended over the northern half of the Palæozoic axis, as evidence of litoral and even of estuarine and terrestrial conditions were met with in the Great Oolite at Meux's boring. The Lias Rhætic and Inferior Oolite having thinned out eastward from Normandy

and the West of England are absent under London and in the Boulonnais.

P. 749.—"The Poikilitic (?) strata" in the Richmond boring described as Sandstones, of red, white, and greenish tints, sometimes very fine grained, and perfectly laminated, the laminæ being covered with white mica flakes, sometimes coarse grained and bedding obscure. The alternating Clays or Marls are of a dark red colour, with green spots and blotches; they are highly indurated and much jointed. The alternations are sometimes in thin layers, sometimes in beds of from two to three feet of Marl. A detailed account of these strata is given.

P. 750.—Some of the cores afford clear evidence of false bedding. The dip is probably 30°; down to the Poikilitic the beds are approximately horizontal.

P. 751.—The induration of the cores no argument against the Triassic age of these beds. Messrs. Gosselet, Six, and Barrois, on inspection referred them to Trias.

P. 753.—The Kentish town rocks are said to be much less like Poikilitic than those of Richmond. Mr. Whitaker's argument against the Old Red Sandstone age assigned to them by Prestwich—the proximity of true Devonian at Meux's and Turnford—is alluded to.

APPENDIX F.

REFERENCES TO CULM MEASURES.

From the Coal Commission Report

Vol. ii, p. 512. By Godwin Austen.—"From the line of the thin seams of Bideford Coal or Culm (Lower Coal Measures), there extends south for 30 miles a tract which presents an endless alternation of fine sandy beds with mud deposits (now slates), the whole so crumpled up into east and west folds that they at present occupy very much less space than at the time of their horizontal deposition. This series, though wholly wanting in seams of workable coal, is referable to the same

general period as that of the higher portions of the South Wales productive Coal Measures. Along the northern edge of this basin, and for great distances outwards, Coal-growth terrestrial surfaces alternated repeatedly with accumulations of sand and silt wherever those surfaces became submerged. Perhaps a nearer approach can be made towards the restoration of this great south-west Coal Measure area to its original physical conditions than can be done for any other like area belonging to our island.

"From the position and relations of the Coal Measures of the St. David's district (South Wales) it may be inferred that the great South Wales Coal basin had its limit against a land surface, somewhere in that direction, whilst on the extreme south a like boundary is marked by the beds which come unconformably upon upturned Devonian Slates and Limestone (Newton); still more clearly by the great bands of shingle, as above Ugbrooke (Chudleigh).

"Throughout its continuance the Culm series area received the drifted spoil from a terrestrial vegetation. It may perhaps be safely assumed, from the absence of any forms of animal life, such as inhabit water, that the condition of the area was unfavourable, as that the water was brackish, a supposition which receives support, from what may be observed in the neighbourhood of Exeter, where masses of Goniatites are to be seen entombed in Culm Shales, as if these free swimming Cephalopods had been drifted in and there killed by meeting with a medium unsuited to them. In this case we have an indication of the direction of the open sea of the period. By combining these several considerations derived from the breadth of the productive Coal growths, and that of the areas over which they are known to have been less so, or not at all, the general area along the south of our island, over which such Coal Measures as may have escaped denudation may be likely to prove productive becomes sufficiently defined along a line extending from Somerset eastwards."

Vol. i, p. 163.—Mr. Prestwich, in his report, says, "We agree with Sir R. Murchison that the Culm Measures of Devonshire point to a rapid deterioration of the Coal Measures in that direction."

Vol. ii, p. 421.—Mr. Etheridge considered "those beds which lie south of Barnstaple" to be equivalent to "the impure Coals of the Millstone Grit series," and above the Mountain Limestone.

Vol. ii, p. 422.—Mr. Prestwich asked Mr. Etheridge highly suggestive questions as to the setting in of Upper Coal Measures in the easterly range of the Culm Measures—to which he replied "All through the Bude trough you see no Coals. It is possible that east of this they may come in again." "Throughout all the country, from Appledore to Boscastle, you see no coal in the Upper beds of the series."

Mr. Etheridge said that the Bideford Coal or Anthracite had been worked at a depth of 300 or 400 feet, but that it was cheaper to bring South Wales Coals to Bideford than to work it.

APPENDIX G.

ON STRIKES.

From the Coal Commission Reports.

Vol. ii, p. 511. Godwin Austen.—"Sir H. De la Beche has remarked on the manner in which the north and south lines of disturbance which have been here noticed pass gradually westward, till they join or fall in with the great east and west system of undulations to which the whole of the South of England owes its configuration. This system of undulations commences on the west in the South of Ireland, is continued across South Wales, and from Cornwall to Kent. On the Continent it reappears in the Boulonnais, and extends thence by the axis of Artois, across Belgium into Westphalia. The whole of this line of disturbance corresponds as to date with that of the Penine chain, it was subsequent to the completion of the true Coal Measures, and prior to the whole of the Permian-trias group."

Vol. ii, pp. 425, 426.—The disturbance "which produced our Penine chain, and broke up our Coal fields there, and which has a general direction north and south. The other direction of disturbance is not of a different age, it is what mathematicians would call complimentary to it, and it has a general east and west direction."

Vol. i, p. 147. Prestwich's Report.—"In addition to the

hypothesis of an original connexion of the Coal fields of England and those of Belgium, and to the known fact of a great east and west disturbance anterior to the deposition of the Permian strata, resulting in the elevation of the Ardennes and the Mendips, as described by previous authors, Mr. Hull further shows that there were minor transverse north and south disturbances of later date (between the Permian and the Trias) in the direction of the Penine chain, the action of which was to break up the Coal Measures of the southern area into basins, the positions of which he considers could now be determined with accuracy by prolonging southward the known great anticlinals of the centre and North of England."

Vol. i, p. 162.—Mr. Prestwich doubts whether the axis of the Penine chain, or of other parallel lines materially affected the southern area. "Notwithstanding its full development in Yorkshire and Derbyshire, it is hardly discernible in Warwickshire, where the Coal field lies almost in its direct course." There are traces of it in Normandy, but nowhere else in Northern France. "Admitting, nevertheless, the possibility of the prolongation of the Penine chain, it would traverse the great Coal trough probably at some point underground between Devizes and Abingdon, so that we might on its western flank look for a Coal basin between Marlborough and Devizes."

Vol. ii, pp. 448, 449.—Professor Phillips assumed the continuation of the Mendip axis toward Boulogne, at all events as far as Salisbury, and would have expected to find a Coal field on the north side of it, probably in a succession of basins.

APPENDIX H.

COAL SOUTH OF THE MENDIPS.

Vol. i, p. 163.—Mr. Prestwich says in his Report, "We cannot expect to meet with the Coal Measures south of the Mendips at a depth less than from 1,500 to 2,000 feet. . . . This presumed Coal basin probably ranges on the south of Wells, under the flat lands, along the River Brue, to the Bristol Channel."

Vol. ii, p. 421.—Mr. Etheridge would expect Coal Measures, if any, south of the Mendips, to agree with the lower series of the Bristol Coal field; but thinks sinking for Coal between the Cannington Park Limestone and Weston-super-Mare would not be at all remunerative, and that the depth of Secondary rocks to be penetrated would be 1,000 to 1,200 feet at least.

Vol ii, p. 436.—Murchison thought it probable that lower portions of the Somerset Coal field might be found south of the Mendips, and north of Cannington.

Vol. ii, p. 449.—Ramsay quoted his opinion given in *Mem. Geo. Sur.*, vol. i, 1846, p. 305, "On the supposition that the Limestone was once covered by Coal Measures depends the probable existence of Coal-bearing strata beneath the alluvial flats of East Sedgemoor." Further he points out, that the low level of the Coal Measure surface, on the north of the Mendips, under the Trias, affords evidence of the probability of Coal Measures existing, under the low ground, to the south-west of the Mendips, that the Lias and Trias, exclusive of overlying deposits, could not be safely reckoned at less than 1,200 feet in that direction. He roughly estimated the breadth of the supposed basin as 12 miles; and said, "What may be the cause of its termination, if the Coal field existed there, I do not know. Whether the Limestone crops up to the south, under the Marshes, or whether, as appears to be likely, the whole is cut off by a north-east and a south-west fault, I am quite ignorant of."

Vol. ii, p. 500.—Professor J, Phillips said, "I judge, however, that it would be unsafe to attach much importance to the expectation of Coal being found on the south side of the (Mendip) axis, from seeing what happens in the whole line of country to the eastward and westward, and from noticing that the Coal in Devonshire is of a poor and miserable character."

APPENDIX I.

From the Coal Commission Report.

Mr. Godwin Austin alluded to the existence of a great Fault cutting off the North Devon Devonian on the north, in the following passages:—

Vol. ii, p. 511.—"The South Wales Coal field had also an extension over the southern portions of Pembroke and Glamorgan, having been denuded off from that low east and west anticlinal range, and it is possible, from the dip of the Mountain Limestone beneath the level of the Bristol Channel, that some portion of the Coal Measures may occur along the line of the great upcast fault of the North Somerset coast line." "The nature and amount of this great upcast, which equals, in the vertical displacement of the series of depositions affected by it, anything to be observed in Belgium, is this, that from the South Somerset range (Foreland) southward, the complete succession of 'Upper Old Red Sandstone,' the 'Devonian' (in its litoral facies), and the Lower Carboniferous (marine) are exhibited, followed by the Culm series of North Devon. Every geologist who is acquainted with this district will concur in the view of Sir R. Murchison, that the Culm or Coal Measure series of Devonshire was, 'at one time, a mere extension of the Pembroke strata of the same age.'—Siluria ch x, xi."

Vol. ii, p. 512.—"Just as the original continuity of the Midland Coal fields of England was broken up by the Penine chain (north and south), so in this case, the great southern expansion of the Coal growth surface was severed by the Somerset and North Devon range. From the southern edge of the Welsh Coal field, across to the Bideford Coal, is an interval of about 100 miles, but this represents a portion only of the breadth of the Coal Measure area on the south."

APPENDIX J.

THICKNESS OF TRIASSIC, LIASSIC, AND OOLITIC STRATA.

From the Coal Commission Report.

Vol. ii, pp. 445, 452, 454, 455. Bristow's Evidence.—

New Red—	*Feet.*
In Compton Dundon boring proved to a depth of	609
Estimated thickness South of the Mendips,	800 to 1,000
Glastonbury	over 400

	Feet.
Lower Lias—	
Lamyatt, six miles south of the eastern extremity of the Mendips	450
Lyme Regis, p. 445, said to be 635 feet, but in Tables, p. 455	446
Glastonbury ... ... over	320
Marlstone—	
Mosterton	280
South Cadbury and Milborne Port	100
Glastonbury	50 to 60
Ridge Barn Hill, near Castle Cary	50
Scale Hill, Batcombe, near Bruton	21
Upper Lias Sand—	
South Cadbury and Milborne Port	240
Mosterton	180
Ridge Barn Hill, near Castle Cary	165
Glastonbury	160
Scale Hill, Batcombe, near Bruton	66
Inferior Oolite—	
Between Cadbury Camp and the Chalk to south-east of it	90
Mosterton	40
Postlebury Hill, south-east of Frome	60
Fullers' Earth—	
Between Cadbury Camp and the Chalk to south-east of it	430
Mosterton	300
Postlebury Hill, south-east of Frome	190
Scale Hill, Batcombe, near Bruton	179
Forest Marble—	
South-east of Milborne Port	450
Postlebury Hill, south-east of Frome ...	130 to 250
Cornbrash—	
Between Cadbury Camp and the Chalk to south-east of it	40
Postlebury Hill, south-east of Frome	30

	Feet.
Oxford Clay—	
Between Cadbury Camp and the Chalk to south-east of it	500 to 600
Postlebury Hill, south-east of Frome	330
Kimeridge Clay—	
At Kimeridge	530
At Swindon	275

Vol. ii, p. 499.—Professor J. Phillips estimated the thickness of the Secondary rocks in the Chalk districts of Wiltshire at 3,000 feet.