On a Boring at Puriton, near Bridgwater, in Search of Coal South of the Mendip Hills.

BY JAMES McMURTRIE, F.G.S.

THE idea of a Boring for Coal at Puriton originated with Mr. Christopher W. M. Greenhill of Puriton Manor, who, having inherited it from his father, requested the writer to give some preliminary advice on the subject ten years ago. The investigations then commenced, having for their object the exploration of estates at Pawlett, Puriton, Knowle and elsewhere, were resumed at intervals in subsequent years, but it was not until the year 1908 that the writer prepared a formal report which led to the recent undertaking.

For that purpose a company, consisting of local landowners and others, was formed, the leading promoter being Mr. Ernest Jardine, M.P., of the Abbey House, Glastonbury, to whose substantial support it was largely due that the boring was ultimately carried out. It is well that the origin of an enterprise, conceived and carried out with so much spirit, should be placed on record in the *Proceedings* of this Society.

Historical.

It is a matter of early geological history that both Dr. Buckland and Sir Henry de la Beche had formed a favourable opinion as to the possible extension of the Somerset coalfield to the south and west of the Mendip Hills. In the year 1846

Sir Andrew Ramsay, who followed them, gave a section showing, to use his own words, "that the Mendips must have broken through an overlying mass of Coal Measures, of which one disjointed portion is partly exposed on the north side, while that on the south possibly exists concealed by the newer rocks." In the year 1871 it formed the subject of a careful enquiry before a Royal Coal Commission, when Mr. Godwin Austin and others gave important evidence bearing on the question, the general finding of the Commission being in favour of the existence of a South Mendip Coalfield; and, as time has gone on, this view has obtained a stronger hold on the minds of most scientific men who have turned their attention to the subject.

The latest writers on this question have been Professor Boyd Dawkins, of the Victoria University, Manchester, and Messrs. Horace B. Woodward and W. E. Ussher, of the Geological Survey, who have all taken a favourable view of the prospects south of the Mendip Hills. Mr. Woodward, who surveyed the district and wrote the Geological Survey Memoir "On the East Somerset and Bristol Coalfields," in 1876 (pages 46 and 47), expressed the opinion that "the probable occurrence of Coal Measures in this southern tract is fully warranted by the anticlinal structure of the Mendip Hills," and that "probably no tract in England offers a greater likelihood of concealed Coal Measures than does this area . . . bounded by the Quantocks above Bridgwater."

Mr. Ussher has embodied his views in a series of valuable papers to this and other societies, his opinions being for the most part favourable. In his official memoir on "The Geology of the Quantock Hills and of Taunton and Bridgwater" (page 38), he expressed the opinion that between Wells, Chapel Allerton, Burtle and Bason Bridge, "the prospects of the occurrence of basins of Upper Carboniferous rocks are very strong," and that although it was "possible that such basins might exhibit the unproductive Devon type . . .

there was no proof that productive Coal Measures might not occur at a depth of 1,000 to 1,500 feet."

Amongst practical mining men should be mentioned the name of the late Mr. George C. Greenwell, F.G.S., formerly of Radstock, who was well acquainted with the district under consideration, and often expressed a decided opinion in favour of the occurrence of a Coalfield to the south of the Mendip Hills.

The writer, on his part, had long held similar convictions. Having, during a long residence in the district, acquired an intimate knowledge of the known Coalfield to the north of the Mendips and of the geological conditions on which the prospects south of the hills must depend, all the circumstances within his knowledge seemed to point conclusively to the possibility and in favour of the probability of the existence of a Coalfield to the south of the Mendip Hills, and he had advocated those views in a series of papers contributed to this and other societies.

Geological Conditions.

The geological basis on which all such opinions have been formed is that the Mendip range, which forms the southern boundary of the known Coalfield, is not the edge of the basin in which the Carboniferous strata were originally deposited, but that, in the words of Sir Andrew Ramsay, already quoted, the Mendips broke through an overlying mass of Coal Measures which may have extended a considerable distance to the south-west. Although bearing evidence of periclinal movements, the Mendip elevation is for the most part a typical example of anticlinal structure, the strata on the northern flank dipping northwards and on the southern flank dipping southwards from a central ridge of Old Red Sandstone and Silurian, the strata which appear on one side of the ridge being for the most part repeated on the opposite side. As a matter of fact the Mountain Limestone shales,

Mountain Limestone and Millstone grit of the northern slopes are all found in their proper order on the south side, and there is no geological reason why the Coal Measures, which come next in ascending order, should not also be found there, although hidden by newer formations, as they also are under large areas of the known Coalfield lying to the north of the hills.

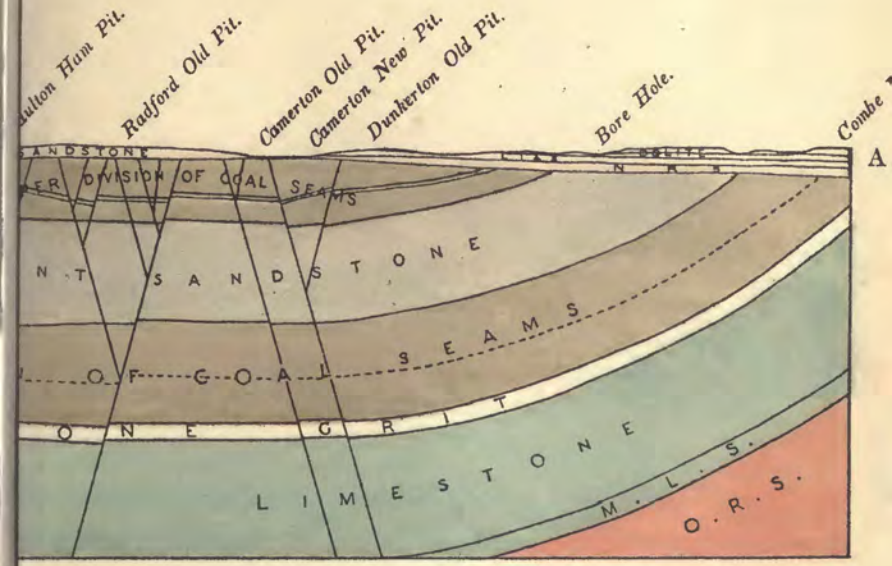
The geological conditions of and adjoining to the Mendips being thus favourable to an extension of the Coal Measures, a question has naturally arisen as to their probable limits to the south and west. In the country stretching away westwards the strata met with at or near the surface are in descending order, Alluvial deposits, Lias, Rhætic and New Red Sandstone, which are well seen near the Polden Hills, but these formations being all higher in the geological order, their presence is in no way inconsistent with the existence of Coal Measures beneath. The nearest elevation of the older rocks in that direction is at Cannington Park, where, to all appearances, the same Mountain Limestone which dips beneath the marshes near Wells, again emerges from beneath the newer formations and may thus possibly mark the south-western boundary of a Coal basin lying under the intermediate area. The Cannington Limestone, which is almost identical in structure with the same formation at Bleadon, is now generally accepted as true Carboniferous Limestone, and it is therefore a valuable landmark in defining the area within which productive Coal Measures may possibly exist.

In order to illustrate what the writer has endeavoured to describe, attention is directed to a Section from Combe Down to Chewton Mendip, passing through one of the best-known and least-disturbed parts of the known Coalfield from east to west. (See Plate I, fig. 1, A to B.) It shows the overlying formations from the Great Oolite down to the New Red Sandstone resting unconformably on the upturned edges of the Coal Measures, the basin form of which is conspicuous

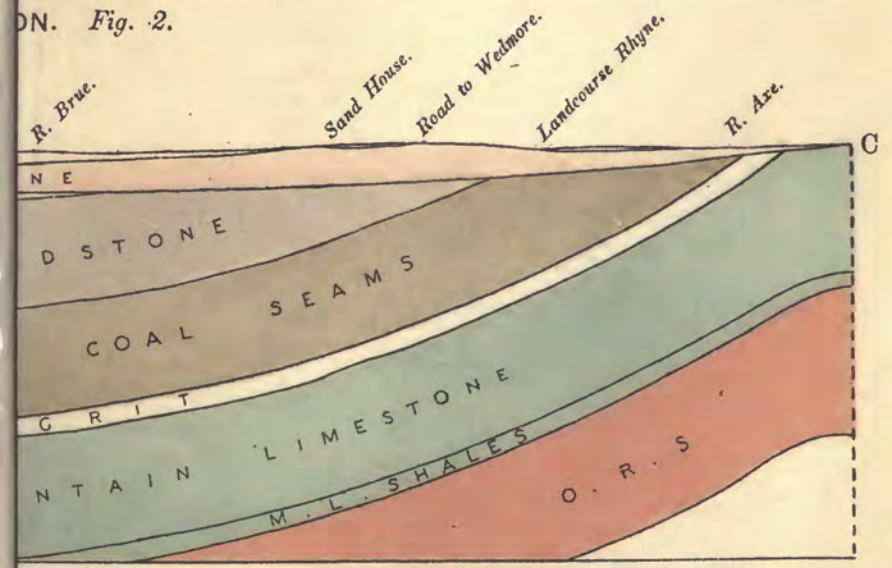
'O CANNINGTON.

PLATE I.

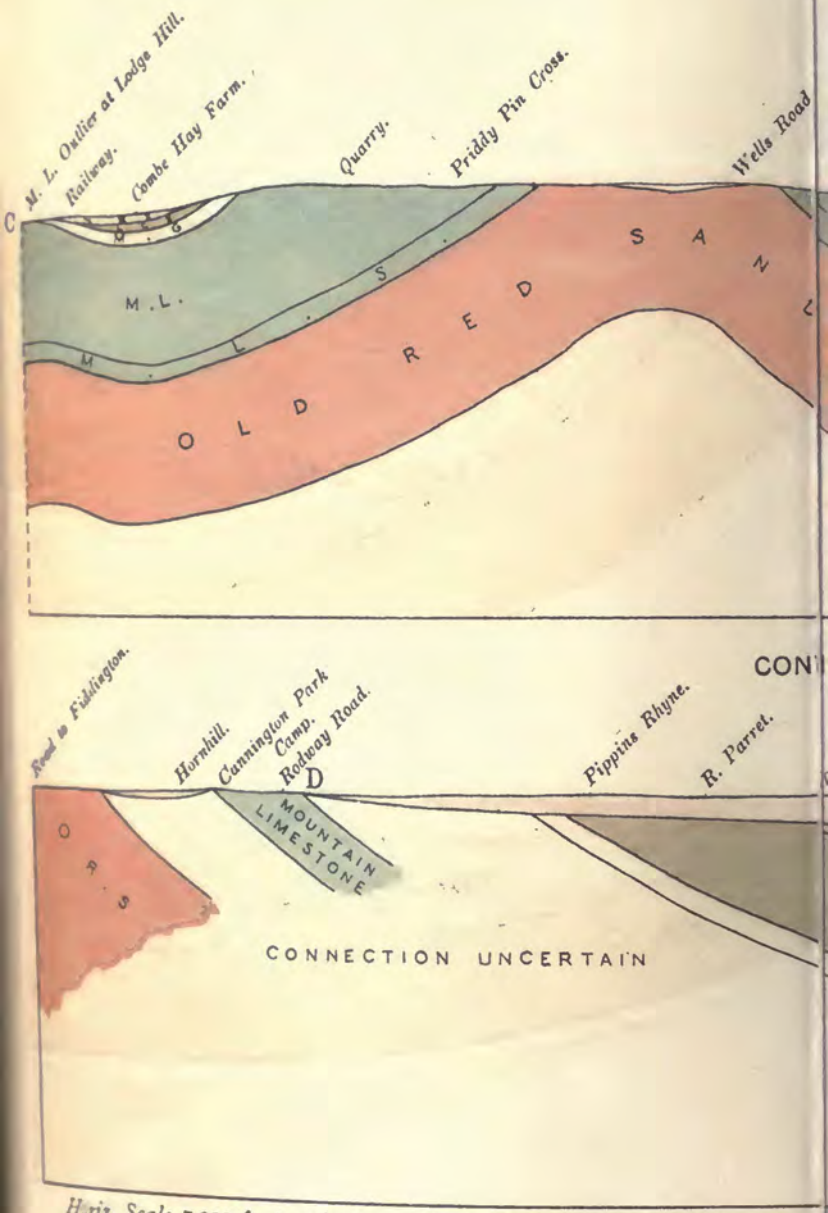
RSET.



ON. *Fig. 2.*



To Il

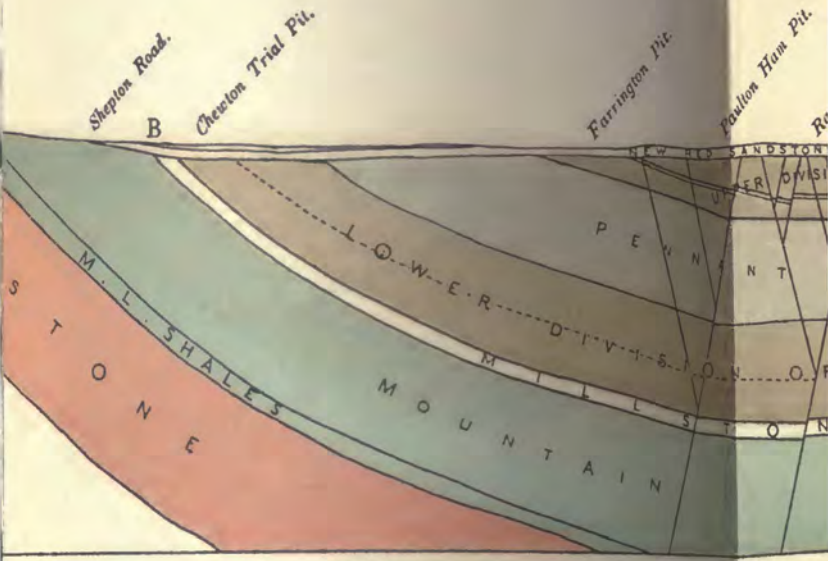


Horiz. Scale 7,000 ft. to 1 inch. *Vert. Scale 5250 ft. to 1 inch.*

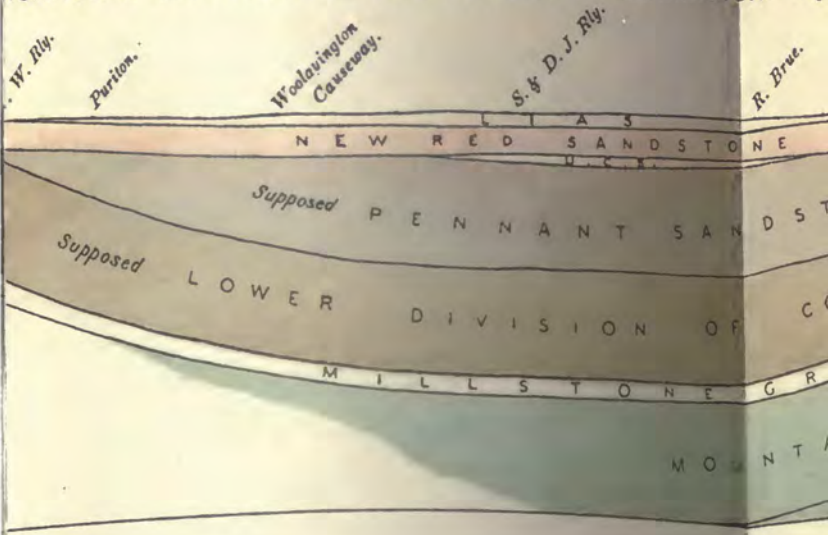
TION FROM COMBE DOWN THROUGH CHEWTON MENDIP TO CANNI

STRATE MR. J. MCMURTRIE'S PAPER ON A BORING AT PURITON, SOMERSET.

Fig. 1.



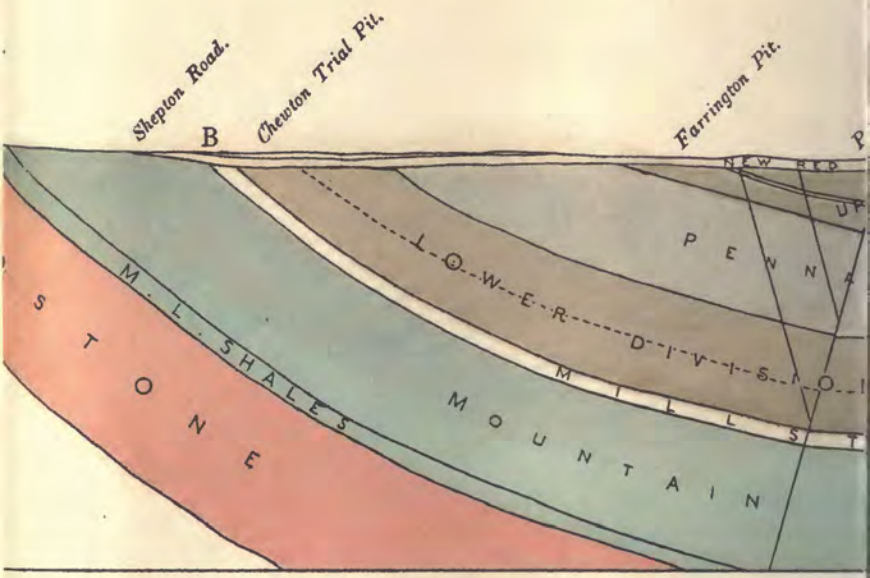
NUATION OF SECTION FROM THE MENDIPS TO CANNINGTON. *Fig*



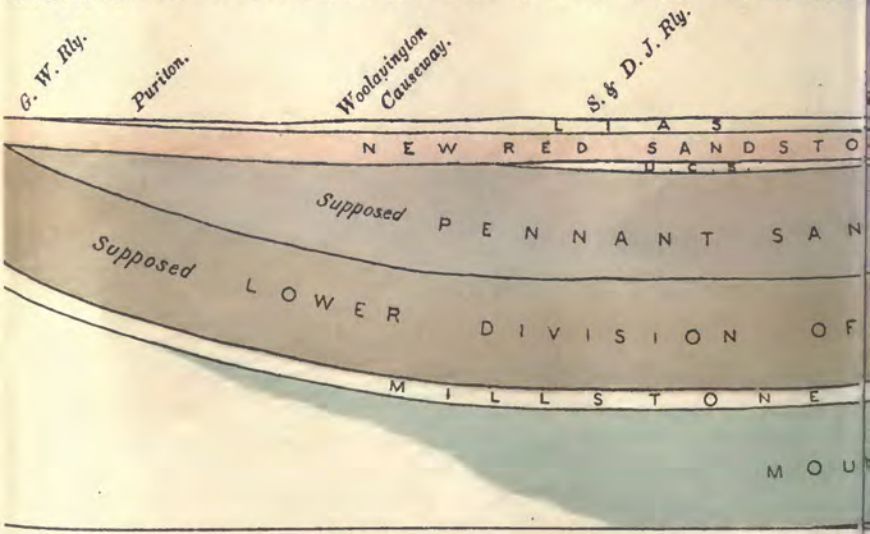
ECTION FROM COMBE DOWN THROUGH CHEWTON MENDIP T

LUSTRATE MR. J. MCMURTRIE'S PAPER ON A BORING AT PURITON, SOMI

Fig. 1.



TINUATION OF SECTION FROM THE MENDIPS TO CANNINGT



ET.

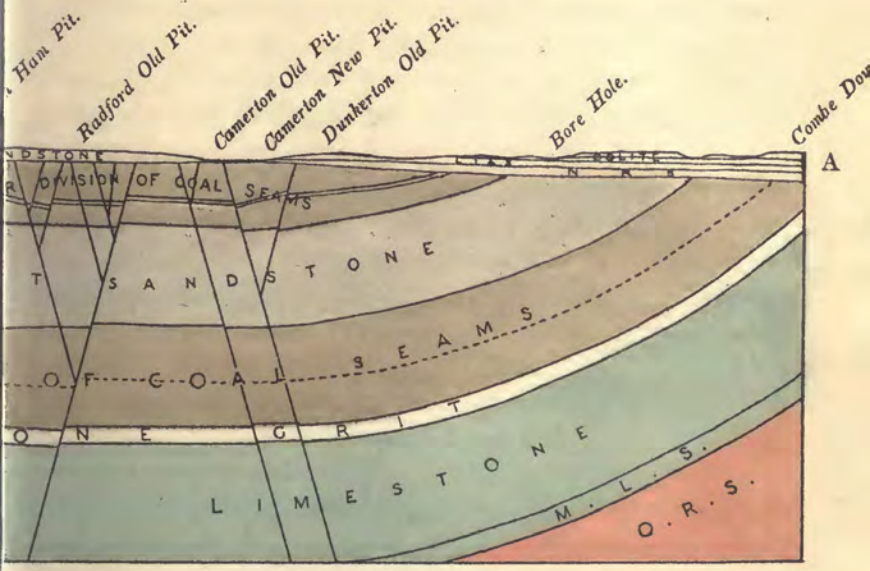
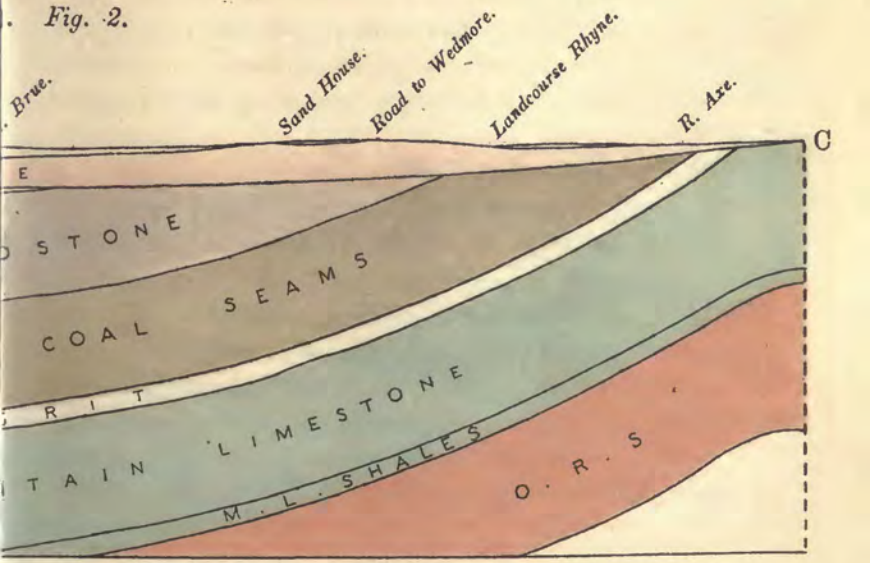

Ham Pit.
Radford Old Pit.
Camerton Old Pit.
Camerton New Pit.
Dunkerton Old Pit.
Bore Hole.
Combe Dow
A
DIVISION OF COAL SEAMS
T SANDSTONE
OF COAL SEAMS
ONE GRIT
LIMESTONE
M.L.S.
O.R.S.

Fig. 2.


Brue.
Sand House.
Road to Wedmore.
Landcourse Rhyne.
R. Axe.
C
STONE
COAL SEAMS
RIT
TAIN LIMESTONE
M.L.SHALES
O.R.S

in this section, its western margin at Chewton being cut off by the anticlinal elevation of the Mendip Hills. The section also shows what the writer has pointed out in former papers to this Society, that, between the close of the Carboniferous period and the deposit of the New Red Sandstone, there must have been great physical disturbances, leading to enormous elevations of the older rocks, which were afterwards extensively removed by denudation, the New Red Sandstone being ultimately deposited comparatively level on their denuded surface at the bottom of a tranquil sea. The thickness of strata so denuded, which on the summit of the Mendips cannot have been far short of 15,000 feet, does not, however, come within the scope of the present paper, and is only mentioned incidentally in order to explain the physical conditions of the district through which the section passes.

To throw light on the country to the south of the Mendip range, an extension of the section has been added, extending across the hills, near Wells, and crossing the flat country towards Bridgwater. (See Plate I, fig. 2). It was prepared before the Puriton boring had been commenced, its object being to define approximately the Carboniferous basin C to D, believed to exist between Wells and Cannington, together with the overlying formations expected to be met with, the Devonian outliers of the Quantocks appearing at the south-western end of the section. One of the difficulties in the construction of this section was a series of isolated areas of Mountain Limestone occurring at Nylands, Lodge Hill (at C on the Section). Wookey and south of Dinder, which, separated as they are from the main ridge of the Mendips, are difficult to account for. The section has assumed that, subordinate to the main physical disturbance, a narrow synclinal basin and anticlinal ridge may lie parallel with the Mendip range, another possible solution being to assume the existence of a great slide or vertical fault, but there is at present no evidence of either.

Some obscurity will be observed at the western end of the

section, the relative positions of the Cannington Limestone and of the Devonian inliers of Charlinch, Radlet Farm, Padnoller and Cannington being surrounded with uncertainty. Mr. Ussher considers it almost certain that the intervening newer rocks must conceal a pre-Triassic fault or thrust occurring between the Cannington Limestone and the Devonian to the south of it; and, under the circumstances, the writer has thought it best to leave that part of the section incomplete, with an intervening break, to allow room for a possible extension of the Limestone to the eastward under the overlying formations.

Former Explorations.

Such being its geological structure, it is not surprising that at various times attempts have been made to prove the country to the south and west of the Mendip Hills.

One of the earliest instances on record was in the year 1815, when the then Earl of Ilchester, under the advice of Mr. William Smith, the pioneer of English geology, put down a trial shaft at Compton Dundon on the south-western side of the Poldens. It began in the Keuper Marls of the New Red Sandstone, in which it was continued to a total depth of 175 yards, when it was abandoned without meeting with success. Particulars of the strata passed through have been published in a paper "On Abnormal Secondary Deposits," contributed by the late Mr. Charles Moore to the Geological Society in March, 1867, and they appear to have consisted of the ordinary red and variegated marls.

In the year 1835, a trial shaft was sunk in the New Red Sandstone at Easton, near Wells, and reached a depth of 70 yards, without accomplishing any practical result. Another trial is said to have been made by a former Bishop of Bath and Wells, and a seam of Coal from six inches to one foot thick is said to have been discovered; but all information on

the subject appears to have been lost and the authenticity of this alleged discovery may be open to doubt.

Next in order, probably, came the borings put down by the late Mr. Greenhill, at Puriton, which are said to have reached a depth of 300 feet in the New Red Sandstone, at which depth they were abandoned.

A more recent exploration was made on the late Earl of Cork's estate at Marston, where a boring was put down in the Oxford Clay, and abandoned at a depth of 600 feet, having been commenced too high up in the geological order to give it any chance of success.

Although in every instance which has been mentioned the attempts were unsuccessful, it only shows that none of the borings went deep enough to pass through the overlying formations, which have been the great obstacle to success in the area under consideration.

In addition to the trials for Coal alluded to, various borings for water and other purposes have been made throughout the district, amongst which the following may be mentioned :—

Boring put down by Mr. Strangways at a farm near Shapwick Station :

Peat, clay, sand, etc.	60 feet.
Lias and other rocks not described	202 ,,
Total ...	262 ,,

Boring at Messrs. Starkey, Knight and Co.'s Brewery, Bridgwater :

	Feet.	Inches.
Made ground	10	0
Red and blue marl stone	12	0
Red marl	28	0
Red sandstone	70	0
Hard red sandstone	1	6
Ditto ditto	12	6
Red marl with layers of rock	64	0
Hard red marl	2	8
Very hard red marl with layers of rock ...	101	1
Total ...	301	9

Boring for water at East Huntspill School, 600 yards south of Bason Bridge:

	Feet.	Inches.
1. Clay	15	0
2. Compressed peat (Pill Coal)	9	0
3. Soft ooze or mud	30	0
4. Quicksand many feet thick, supposed to be an old sea bottom	446	0
5. Hard blue clay		
Total ...	500	0

This boring is instructive, showing as it does Alluvial deposits and Blue Clay to a depth of 500 feet without, apparently, having reached the New Red Sandstone, and it would indicate an unusual thickness of overlying strata in that locality.

These are a few of the leading borings in the area between the Mendips and the Quantocks, and there may have been others; but none of them were of sufficient depth to prove the thickness of the overlying formations. In the absence of direct evidence, widely diverging estimates of their thickness have been made by various authorities.

The late Mr. Charles Moore, whose painstaking work in the west of England will ever be remembered, does not seem to have attempted any positive estimate, but in his paper, "On Abnormal Secondary Deposits," already referred to, he has drawn the following striking comparison between the thickness of the overlying rocks within the known Coalfield and the greatest thickness of the Secondary beds without the Coal basin:

	Without Coal-basin. Feet.	Within Coal-basin. Feet.
Triassic beds	2000	50
Rhætic beds	50	50
Lower Lias	700	2
Middle and Upper Lias ...	500	42
Inferior Oolite	170	25
	3420	169

In this comparison the depths within the Coal basin have been rather understated, and those without the basin possibly

overstated, the greatest depths having been taken from different localities, which could hardly be expected at any one point.

In seeking to account for this great disparity, Mr. Moore has pointed out that, after their first elevation, the Mendips had seldom, or, perhaps, never been entirely submerged. They had formed a Carboniferous island, which, for many ages, proved a barrier to the incursion of the deeper sea deposits which were taking place to the south, in which were being accumulated the materials composing many of the Secondary rocks.

In the Report of the Royal Coal Commission, 1871, to which allusion has already been made, Mr. Prestwich estimated the Lias to the south of the Mendips at from 400 to 500 feet, and the New Red Sandstone at from 500 to 800 feet; so that, where both of these formations were present, the total thickness might be from 900 to 1,300 feet to reach the older rocks.

In the Memoir of the Geological Survey by Mr. Horace Woodward, he estimated the maximum thickness of the Lias in the valley of Ilchester at 350 feet, and of the New Red Sandstone at 800 feet, making a total of 1,150 feet. But farther north, as at Meare and Wedmore, he thought the Coal Measures might reasonably be expected at 1,000 feet. Mr. Ussher formerly adopted a similar view; but, in a later geological memoir, he expressed the opinion that the depth to the older rocks might be from 1,000 to 1,500 feet.

The question of depth obviously depended very much on the presence or absence of the lower members of the Trias and Permian from the Bunter downwards, none of which had been met with in the known Coalfield north of the Mendips, or had hitherto been discovered in the Bridgwater area, a branch of the subject which will be more fully dealt with in a later part of this paper. It also depended very much on the geographical position of the proposed boring, for any boring north of the Polden's must necessarily pass through

a considerable thickness of alluvial deposit, Lias and Rhætic —before reaching the New Red Sandstone, while immediately to the south of those hills it would begin in the upper part of the New Red formation almost at once. After a careful consideration of all the circumstances, a site was selected between Puriton Hill and the Sedgmoor Drain, 640 yards east of Dunball Station, where an abundant supply of water was obtainable, an important requisite in boring operations.

Puriton Boring.

The site having thus been decided, a contract was entered into with Vivian's Boring and Exploration Company, Ltd., of Cleator Moor, Cumberland, a firm possessing great experience in such work, and, after some necessary delay in the erection of plant, boring operations were commenced in December, 1909. The apparatus supplied was the diamond boring machine, using chilled shot, with provision for the use of a diamond drill in passing through minerals requiring special care. Having reason to anticipate a deep exploration, the boring was commenced with a diameter of 17½ inches, which was maintained until it reached a depth of 49 feet, after which it was reduced from time to time as became necessary in lining the hole, the following being the dimensions at various depths :

Depths.		Diameter of Bore-hole.	Diameter of Core.
From.	To.		
Feet.	Feet.	Inches.	Inches.
Surface	49	17½	None obtained
49	711	14½	13
711	1036	12⅜	10¾
1036	2072	10¾	9½

The boring reached the depth of 2,072 feet 4 inches on the 24th November, 1910, having occupied nearly twelve months, being at the rate of 173 feet per month, including occasional

I. Keuper.

II. Upper Sandstones.

III. Bunter Pebble Bed.

V. Lower Sandstones.

Squibbs & Carey, photographers, Bridgwater.

GENERAL VIEW OF CORES AT THE PURITON BORING.

stoppages. Out of the total depth bored, 1962 feet of core was brought to the surface and ranged in consecutive lines within the boring enclosure, their fine appearance being generally remarked upon by visitors, some of whom had seen similar operations elsewhere.

Duplicate cabinet specimens were also taken at regular depths, and upon every change in the strata, one set having since been presented to the Society's Museum at Taunton Castle, and the other to the Bristol Museum, where they will be carefully preserved for future reference.

Photographs of the cores were taken at the close of the boring operations, and a reduced copy of one of these will be found on Plate II. The bottom cores appear in the foreground, and the others in ascending order, ranging from left to right.

In order that full particulars of this exploration may be preserved, a copy of the boring record is given in an appendix to this paper. The chief points of interest connected with the work may be summarised as follows :

Alluvial Deposits :—From the surface down to a depth of 23 feet, the ground consisted of clay of the description usually met with in the Bridgwater area. A bed of sandy shale, one foot in thickness, occurring at that depth seemed to drain off the water from the bore-hole into the adjoining stream, for whenever boring operations ceased, the water in the hole always fell to that level.

Keuper :—After passing through the superficial beds, the boring entered the Keuper Marls of the New Red Sandstone, which, for the first 589 feet, differed little from the same formation in other parts of the county. The red marl was as usual the predominating feature in the entire deposit, but it was interspersed at irregular intervals with thin beds, streaks and spots of bluish-green, generally harder than the red marl in which they occurred. The upper part of the deposit was of a soft and friable character, and under the influence of sun and rain some of the cores gradually crumbled away; but in

going downwards the marls became more indurated, being in places fairly hard.

As will be seen from the section, Gypsum was frequently present, few drawings of the core being free from it. Some times it occurred in thin streaks or veins, passing diagonally or nearly vertically through the marls; in other places it was obviously interstratified with the marl, for the most part in very thin layers of from half-an-inch to an inch or two in thickness; but at a depth of 359 feet 5 inches the boring passed through a bed of Gypsum 2 feet in thickness, being the only one calling for special notice. It was very striking to find this pure white substance, so different in appearance and chemical composition, occurring in these variegated marls, and indicating recurring changes in the character of the deposit laid down in the Triassic sea.

Between the depths of 589 and 608 feet a marked change was observable, the beds of red marl being interspersed with dark blue shale and breccia, which preponderated, with occasional small cavities lined with crystals and, in one instance, with a dark cindery-looking substance of a peculiar kind. This change seemed to be the precursor of a new discovery which will always be associated with the Puriton boring, viz., the presence of a considerable Salt deposit, not previously met with in the south and west of England.

The first indications of this discovery were observed by the writer in certain cores of red and dark blue marl with breccia at a depth of 611 feet, which contained crystals of Rock Salt. Below this point the strata became very jointy and broken, with occasional indications of false bedding, conveying the impression that the bore-hole might be passing through a fault, but of this there was no conclusive indication. In consequence of the broken nature of the ground, it became difficult to obtain satisfactory cores as formerly, but sufficient was recovered to show a continuance of the red and blue marl, varied by an occasional bed of grey shale or sandstone.

It may be mentioned that in Yorkshire, where large deposits of salt have been met with in the Keuper Marls, within the last thirty years, similar rotten strata were invariably found overlying and associated with the salt-bearing ground.

Rock Salt:—The first actual proof of the existence of Rock Salt was obtained from a core between 646 feet 6 inches and 648 feet 8 inches, in red and grey sandy marl with grey sandstone. From there down to a depth of 719 feet 4 inches, Rock Salt, associated with red and blue marl, was recorded from time to time, the range of the deposit being thus about 73 feet in depth. Few, if any, of the specimens obtained afforded proof of continuous beds or masses of Rock Salt, which may have been due to the dissolving of the salt by the water used in the process of boring. In the method adopted, a continuous stream of fresh water is forced down the hollow boring rods to the bottom of the hole, from which it afterwards flows up the hole to the surface, carrying with it the débris produced in the course of the boring operations. In this way any salt contained in the cores or exposed in the sides of the bore-hole may have been more or less dissolved, and there were indications of a considerable cavity having thus been formed around the hole, for débris kept dropping from there to the bottom, until it became necessary to line that part of the hole with steel tubing before the work could proceed. It is to be regretted that, owing to this melting of the salt, coupled with the broken and jointy character of the ground, the cores obtained have not shown with certainty the nature and extent of the salt deposit.

The finest specimens of Rock Salt occurred in a curious form, which has puzzled the minds of experts and others who have examined them, and is very difficult to account for. The specimens in question were five in number and consisted of vertical columns of Rock Salt from 17 inches to 21½ inches in length and from 5½ to 7 inches in diameter, of a semi-transparent light-brown colour, hardly distinguishable in ap-

pearance from the Rock Salt of Cheshire, their outer surface being pitted all over with shallow oval depressions of an irregular pattern. The novel feature was that in each instance they were found in a vertical position in the centre of cores 10½ inches in diameter, being literally encased in red and blue marl, which formed the top, bottom and sides of the cores, and in which the lines of stratification were quite distinct. From this it would appear that where these columns were found, the Rock Salt cannot have been continuous either horizontally or vertically, although similar masses and continuous beds may have existed in the surrounding strata.

In order to explain their structure more clearly, photographs of three of the cores referred to have been taken and subsequently enlarged. (See Plate III, figs. 1, 2 and 3).

In Fig. 1 the crevices in the core show the salt column within, which is almost completely encased in marl about 1½ inches in thickness at the sides, but thicker at the ends, the lines of stratification being well marked.

In Fig. 2, the encasing marl has been broken up during boring operations which appear to have ground the salt column almost to a point at one end, the other being enclosed in marl. The casing of this specimen was more complete when first drawn, but has since been damaged in handling.

In Fig. 3, the casing is nearly perfect at each end, but the middle part has broken away, laying bare the Salt column.

The writer, being unable to account for these strange phenomena, has confined himself to a statement of the facts.

In some instances angular lumps of Rock Salt occurred irregularly in the cores associated with red and variegated marl, whilst in others long attenuated cores of a dark cindery substance from 4 inches to 6 inches in diameter, composed largely of salt crystals, were brought to the surface, the inference being that the rest of such cores had been dissolved during the boring operations.

From these particulars it will be seen that no exact estimate

Plate III.

Cores at Puriton Boring containing Rock Salt.

Fig. 1.

Column of Salt enclosed in stratified Keuper Marl.

Fig. 2.

Column of Salt with Marl stripped off and one end pointed in boring.

Fig. 3.

Column of Salt encased in Keuper, partly broken off.

can be formed from the result of this boring as to the extent or commercial value of the Salt deposit. Mr. Greenhill is of opinion that, if complete cores could have been obtained, they would have shown a succession of stratified beds of Rock Salt of considerable thickness; but experts in the salt industry, who have enquired into the facts on the spot, are of opinion that the facts are to be accounted for by the presence of brine springs. A second boring is now being put down to the north of the first, for pumping the brine for commercial purposes, a preliminary plant being in course of erection for its treatment, so that further information on the subject may shortly be expected.

Until further evidence is obtainable, it cannot be said positively how far the phenomena are to be accounted for by the presence of Rock Salt and how far by the occurrence of brine springs, the latter however being probably attributable to the former, but all the facts undoubtedly point to a considerable deposit of Salt in some form, the best evidence of which, probably, is the continuous yield of brine over a period of eight months from its first discovery until the stoppage of the boring in November last, the following being a summary of the tests made daily with the hydrometer, between July and November, 1910:—

Month.	Number of Tests.		Yield of Salt per gallon.	
			lbs.	ozs.
July	36		1	13½
August	61		1	14
September	59		1	9½
October	46		1	13½
November	33		1	15
Average of	235	tests over 5 months	1	13

When it is remembered that during this period the bore-hole was closely lined with steel tubes all through the salt-bearing ground, so that the brine had to force its way upwards and downwards behind the tubes in order to reach the surface, this

long-continued discharge was very remarkable, its strength increasing rather than diminishing as time went on.

In addition to the above hydrometer tests, the following analyses have been made by Messrs. Waterfall and O'Brien, Analytical Chemists, of Bristol, and show equally satisfactory results.

THE LABORATORY,
4, QUEEN'S SQUARE, BRISTOL,
4th August, 1910.

SAMPLE OF BRINE SENT BY C. GREENHILL, ESQ.

	Parts by weight.	lbs. per gallon.
Sodium Chloride (Common Salt) ...	25·41%	3·055
Calcium Sulphate	0·55%	·067
Calcium Chloride	0·04%	·005
Magnesium Chloride	0·07%	·008
	26·07%	3·135
Specific gravity	1·202	

If evaporated to dryness the residual salt would have the following per centage composition:—

Sodium Chloride	97·47
Calcium Sulphate	2·13
Calcium Chloride	·15
Magnesium Chloride	·25
	100·00

Signed, WATERFALL & O'BRIEN.

For comparison with the above, the analysts furnished the following analyses of some other brines obtained in England, and with which the Puriton sample compares very favourably.

From	Marston.	Wheelock.	Droitwich.	Stoke Prior.	Cheshire Rock Salt.
Sodium Chloride ...	25·22	25·33	22·45	25·49	98·30
Calcium Sulphate ...	·39	·42	·39	·26	1·65
Calcium Chloride ...	—	—	—	—	—
Magnesium Chloride ...	—	·17	—	—	·05
Sodium Sulphate ...	·15	—	·39	—	—
Magnesium Carbonate	·10	·10	·03	·03	—
Calcium Carbonate ...	—	·05	—	—	—
	25·86	26·07	23·26	25·78	100

Before passing from this part of the subject it may be remarked that the Puriton boring, if it has done nothing more, has established the existence in this county of a new and valuable product which may become of considerable industrial importance. The presence of Salt in the New Red Sandstone of Lancashire, Cheshire and Worcestershire, has been known from the earliest times, and the discovery of Salt in the same formation in South Durham and Yorkshire some thirty years ago added greatly to the area of such deposits in England. They were supposed to terminate southwards at Stoke, in Worcestershire, for in the large exposed area of the Keuper, extending through Gloucester, Somerset and Devon, nothing more than a few pseudo crystals of Salt had hitherto been found, either within or without the Coal measure basin. A glance at the geological maps will serve to show what a large area the Keuper occupies to the south of the Mendip Hills, and, should the discovery at Puriton be confirmed and extended by other explorations, it may lead to the establishment of a new industry in the south of England.

After leaving the Salt ground at 719 feet 4 inches, the boring passed into ordinary red and variegated marl, the strata for the next 100 feet being more or less jointy and broken, but gradually becoming harder in going downwards, until the cores became more like marlstone, being very difficult to break off when drawing the rods. Gypsum was still present, sometimes in thin beds and diagonal veins, at other times in spots like white pebbles. In one instance, between 1,177 and 1,178 feet, the Gypsum took a very peculiar form, its vertical section being in the form of a **V**.

Grey Sandstone, Breccia and Conglomerate.—At a depth of 1,279 feet a marked change was observable in the strata, and it continued to a depth of 1,490 feet. Instead of the ordinary red and variegated marl, the boring met with a succession of red, grey and violet-grey beds of sandstone, the latter prevailing, and being so marked that the violet-grey colour of the

cores, when ranged in the yard, stood out in bold contrast with the Keuper Marls met with above. Occasionally the sandstones were of a gritty character, and in several places there were beds of breccia and conglomerate. Between 1,391 and 1,401 feet the strata were partly brecciated ; at 1,417 feet the boring passed through a foot of conglomerate, and at 1,487 and 1,490 feet the red and grey sandstones were again interspersed with conglomerate.

In the last 70 feet of the Keuper (between 1,219 and 1,279 feet), and all through the strata last described, down to the lowest bed at 1,490 feet, the strata were highly calcareous, effervescing freely when tested with acid. This was especially observable in the pebbles contained in the conglomerate, which must have been derived from the Limestone seaboard of some not far-distant shore ; but no fossil remains of any kind were detected during the progress of the boring to establish the age of the strata from which they were derived.

With the appearance of these conglomerates and breccias, meagre though they were, great hopes were formed of the prospects of the boring. In the Chewton and Combe Down section already referred to, and within the known Coalfield to the north of the Mendip Hills, there invariably occurs at the base of the Keuper Marls a remarkable bed of conglomerate known as the Dolomitic Conglomerate, which is well known to all observers. Beginning with a thickness of 50 to 100 feet in the flanks of the Mendips, it diminishes to about 20 feet towards the centre of the basin, the conglomerate resting in all cases unconformably on the Coal measures.

The beds met with at Puriton did not exhibit the massive character described, but it was thought this might be due to different local conditions prevailing on the south side of the hills. During its deposition, the nearest shore line may have been the Devonian of the Quantocks, and the distance from the older rocks in both directions might have prevented the

deposit of conglomerate in continuous massive beds. With his knowledge of the Radstock Coalfield, the writer felt hopeful if not confident that the object of the boring was at last within reach ; but, to the great regret of everyone, these hopes were doomed to disappointment.

Bright Red Marly Sandstone.—At a depth of 1,490 feet, a great change again took place. The red and grey sandstones, grits and conglomerates came to an abrupt termination, and the boring passed into a bright red marly sandstone of a very distinctive character, with occasional blue spots, but almost free from Gypsum and with no trace of calcareous matter. This deposit, which was perfectly homogeneous in its character, continued with hardly any perceptible change to a depth of 2,072 feet 4 inches, at which the boring was abandoned, the only difference being that the lower beds were somewhat less bright red. It had then passed through 583 feet of this deposit, a circumstance which has puzzled experts who have turned their attention to the subject.

Taking the boring as a whole, the contrast in colour and lithological structure presented by the cores as ranged consecutively in the yard was very striking. From the surface downwards the first 17 or 18 rows were of a dull light red colour with streaks of blue, layers of Gypsum and the deposit of Salt, the whole belonging unquestionably to the Keuper formation. The next five rows consisted of grey, violet-grey and dark red sandstone, with beds of breccia and conglomerate, the deposit standing out in striking contrast with the strata both above and below it. The remaining rows of core, consisting of the bright red marly sandstone already described, differed from both the preceding groups, the difference being conspicuous to the most casual observer, and suggesting to the writer that the boring had entered one of the lower groups of the Trias not hitherto met with in the Mendip and Bridgwater area.

Inspection by Mr. W. A. E. Ussher, F.G.S.
Suggested Co-relation.

Under all the circumstances it was thought desirable to obtain a further opinion on the new features which had presented themselves, and, on the writer's recommendation, it was determined to call in Mr. William A. E. Ussher, F.G.S., who for more than thirty years had been engaged on the Geological Survey, in investigating the subdivisions of the New Red rocks and the Devonian System in the south and west of England. His geological contributions to various societies for many years and his Memoir of the Geological Survey on "The Geology of the Quantock Hills and of Taunton and Bridgwater," published in 1908, especially fitted him for the work entrusted to him, and gave his opinion on the subject much importance.

Having informed himself as to the circumstances under which the exploration had been undertaken, as described in the earlier part of this paper, he made a careful study of the boring record and an exhaustive examination of the cores and cabinet specimens obtained from the boring, the following being a short summary of the conclusions at which he arrived.

I.—From the superficial deposits, mostly alluvial, down to a depth of 1,275 feet from the surface, he considered the cores were composed of Keuper Marls, thus proving them to accord closely with his maximum estimate of their thickness, 1,350 feet, in the "Quarterly Journal of the Geological Society," 1876, page 392.

II.—From 1,275 to 1,491 feet the cores consisted of sandstone, degenerating into marl in places and irregularly stratified with marl. These, in his opinion, were certainly Triassic —the Upper Sandstones of his classification.

III.—From 1,491 feet downwards the cores seemed to him to present great similarity. He described them as very fine

grained sandstones of a uniform rather bright red colour, and he regarded them as Permian.

This succession was not what he would have expected, for where these rocks outcrop at about 10-13 miles to the west, the Triassic Sandstones (between 1,275 and 1,491 feet in the boring) are succeeded by Pebbly Sandstones or Conglomerates from 70 to 100 feet thick, resting on Permian or Lower Marls about 200 feet in thickness.

The general succession of the New Red rocks in the south-western counties, between the English Channel and Williton, Mr. Ussher described as follows:—

1.—Keuper Marls proved to exceed 1,129 feet in thickness in the boring near Lyme Regis.

2.—Upper Sandstones, 500 feet on the south coast (proved to be an approximate thickness of 400 feet in Dotton boring, near Budleigh Salterton).

3.—Pebble beds, 70 feet at Budleigh Salterton, passing into Conglomerate 70 to 100 feet near Milverton.

4.—Lower Marls, 500 feet on the south coast, not including marls and sandstones at their base (which may pass into the upper beds of the succeeding division horizontally).

5.—Lower Sandstones and Breccias, probably about 1,500 feet thick on the south coast.

Except where cut out by faults, all these divisions extend continuously from the south coast to the vicinity of Williton, but in tracing their outcrop northwards, numbers 2, 4 and 5 attenuate, especially number 5, the Lower Sandstones and Breccias, which may not exceed 500 feet in the neighbourhood of Stogumber. Number 5, however, no doubt thickens considerably where concealed by the overlying strata to the east of its outcrop.

The identification of the Keuper Marls in the Puriton boring down to a depth of 1,275 feet is, Mr. Ussher considers, not open to doubt, but his first impression was that the cores below that depth might be capable of two very different interpretations.

On a further examination of the cores, however, and having given the subject further consideration, his decided opinion now is that from 1,275 to 1,477 feet the cores represent the Upper Sandstones (No. 2), their thickness in the boring being in accord with their northern attenuation. Also that from 1,477 to 1,491 feet, where the cores contain limestone pebbles in places, the strata may be considered to represent the Conglomerate or Bunter pebble bed (No. 3), its attenuation from 70 or 100 feet at the nearest outcrop, near Combe Florey, to 14 feet in the boring being accounted for by the thinning of the coarse beds as they recede from the older rock margin, their ancient shore line.

From 1,491 feet, downwards, the cores of homogeneous fine grained sandstones may be considered to agree closely in colour and character with the Lower Sandstone, or Permian, of Division 5. The main objection to this hypothesis is the absence of the Lower Marl (Division 4), but this may be explained by the replacement of the Marls by Sandstone of the subjacent type, or by their absence through thinning out.

The homogeneous character of the Lower Sandstone for so great a depth is, in Mr. Ussher's experience, quite unparalleled in the rocks of the south-west of England. Its nearest outcrop being 13 or 14 miles away, he has found it quite impossible to form a definite opinion as to the depth of New Red (Permian) strata yet to be penetrated, or to discover any clue to the nature of the rocks which may lie beneath.

A comparative diagram explaining his views will be found on Plate IV, in which the boring at Puriton is placed side by side with sections at Milverton and the south coast on the one hand and an unpublished boring at Chewton Mendip on the other, the Roman numerals indicating the suggested co-relation already pointed out. It shows the marked difference between the New Red Sandstone on the north and south of the Mendip Hills, also the further variations which present themselves in following that formation southwards,

especially the great increase in thickness towards the south coast.

Before leaving the subject, the writer would desire to express his obligation to Mr. Ussher for the great care he has devoted to this investigation; also for his kind permission to record the result in the present paper.

Conclusion.

Considered from a scientific point of view, it has been a matter of regret to the writer, as it has also been to the Bridgwater Company, that the boring had to be abandoned without having accomplished its purpose. Great hopes had been formed of the undertaking, and it was a great disappointment that, after having gone so far towards the accomplishment of the object in view, its promoters should be forced to abandon it without having solved the great problem of a possible South Mendip Coalfield.

Although, however, this is still left in doubt, the result must not be regarded geologically as an adverse conclusion; it is rather, in the words of the Scottish verdict, "not proven." If there was any reason to suppose that the boring had left off in rocks lower in sequence than the Coal Measures, it would have been otherwise, but all who have seen the series of cores obtained, including some who have devoted a lifetime to the study of the question, are agreed that the boring left off either in the Triassic or Permian formations, in either case higher in the geological succession than Coal.

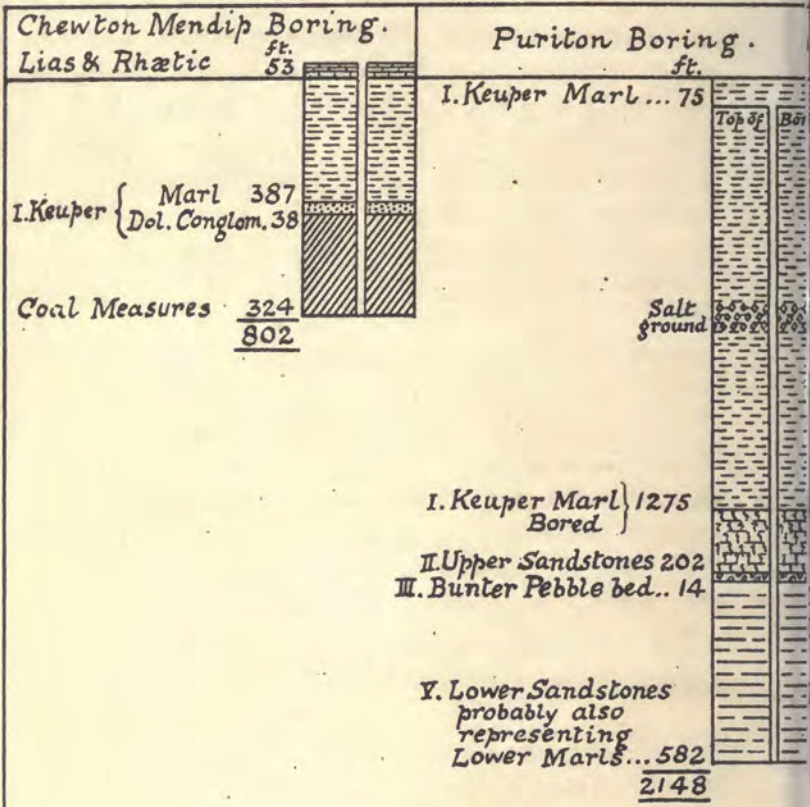
The reasons for the abandonment of the undertaking were that, having regard to the great depth which the boring had reached, the farther unknown depth which might be necessary to reach the older rocks, and the great cost of sinking afterwards, if Coal should be found, the Directors were advised that the enterprise could not, probably, be carried on further with any prospect of financial success. It is true that both in England and on the Continent Coal has been worked

at even greater depths than have been reached at Puriton. According to the report of the "Royal Commission on Coal Supplies, 1905," the deepest Coal mine in England at that time was at Pendleton, near Manchester, with a depth of 3,483 feet, this being exceeded at Produits Colliery, Belgium, with a depth of 3,773 feet, which was then the deepest Coal mine in the world; but at such depths, thick and valuable seams are necessary to commercial success, and at Puriton there was uncertainty as to the character of the seams which might be found.

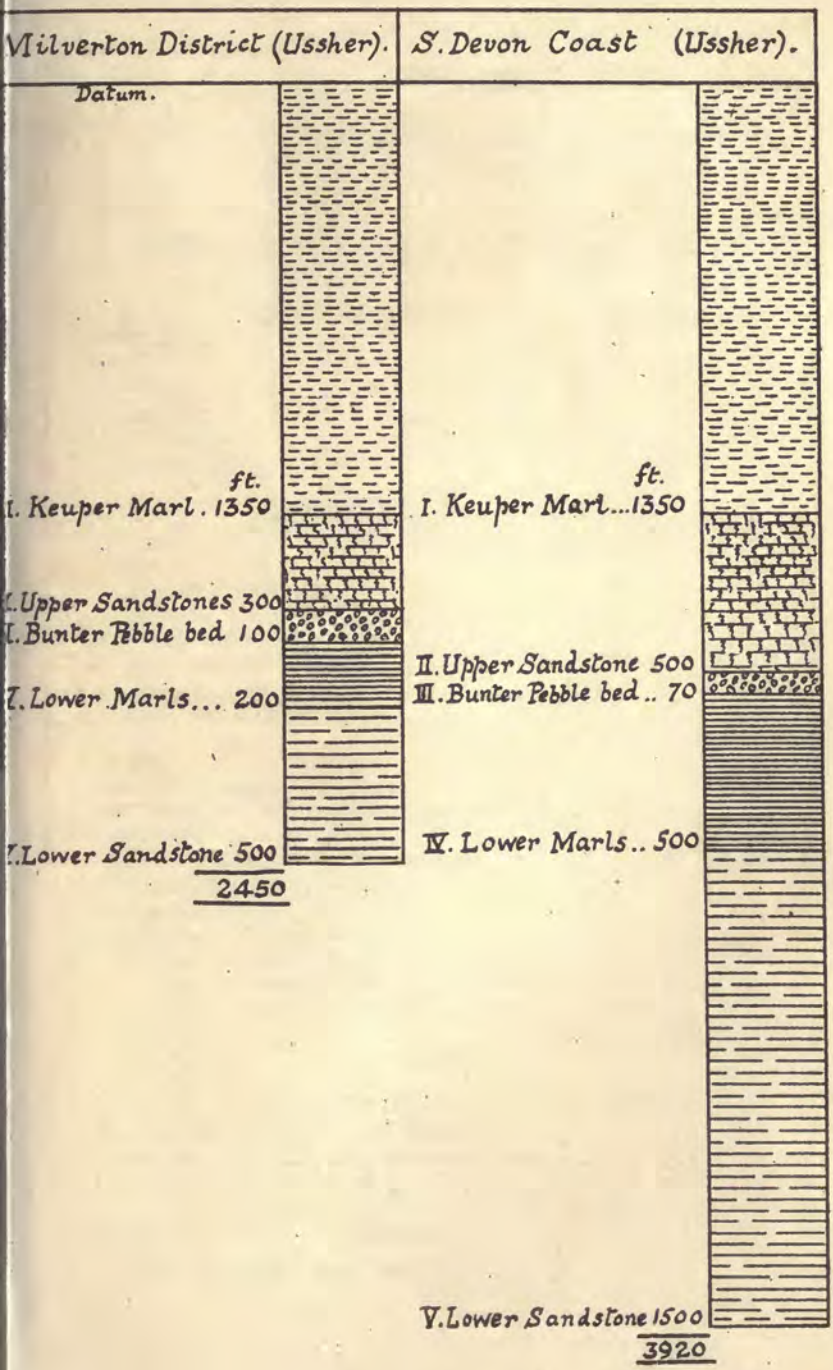
No other site within the Company's sphere of operations suggested any better prospect, for, northwards the alluvial and Liassic deposits would have added to the probable depth, while southwards and westwards any operations undertaken would have been getting nearer the great unproductive Carboniferous area of West Somerset, Devon and Cornwall, where workable Coal does not exist. The Puriton bore-hole, however, remains accessible, and Mr. Greenhill still entertains the hope that at no distant date it may be continued to such a depth as will prove once for all the existence or non-existence of a South Mendip Coalfield.

In the meantime, the promoters are to be congratulated on the fact that the undertaking has not been altogether in vain, the salt discovery having introduced a new industry into the county, which may be capable of considerable development. If the works now in course of construction at Puriton are successful, others are sure to follow; and it will be the desire of all that these undertakings may be attended with success.

COMPARISON OF SECTIONS AT CHEWTO



PURITON, MILVERTON AND SOUTH DEVON COAST.



APPENDIX.

Record of Strata passed through in Puriton Boring near Bridgwater, 1909-10.

Depth from base of Rhætic to top of Boring: Keuper marls about 75 feet.	Depth bored.		Total depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Superficial Deposits.				
Made ground	1	6	1	6
Soil	0	9	2	3
Brown clay	6	6	8	9
Loamy clay	3	3	12	0
Brown clay, soft	10	0	22	0
Grey sandy shale	1	0	23	0
Keuper Marl.				
Red marl	2	0	25	0
Do.	3	0	28	0
Do. with blue streaks	5	0	33	0
Do.	4	0	37	0
Do.	2	0	39	0
Do. with blue streaks	2	0	41	0
Do.	2	0	43	0
Do. with blue streaks	2	0	45	0
Do.	4	0	49	0
Do.	0	5	49	5
Red and blue sandy marl, jointy	10	7	60	0
Red sandy marl with blue spots, very jointy ...	19	1	79	1
Red marl	1	11	81	0
Red and blue sandy marl, very jointy	4	6	85	6
Red sandy marl with blue spots, do.	11	8	97	2
Red and blue sandy marl do.	15	1	112	3
Red sandy marl with blue spots, do.	5	0	117	3
Do. with gypsum	1	10	119	1
Do. with blue spots, very jointy ...	8	0	127	1
Do. with gypsum, jointy	8	3	135	4
Do. do.	20	2	155	6
Do. do. very jointy ...	6	11	162	5
Do. do. do.	23	7	186	0
Do. with spots of blue and gypsum ...	6	5	192	5
Red and blue sandy marl with gypsum	2	7	195	0
Red sandy marl with spots of blue and gypsum ...	9	4	204	4
Do. with gypsum	5	8	210	0
Do. with spots of blue and gypsum ...	10	0	220	0
Red and blue sandy marl with gypsum	9	10	229	10

RECORD OF STRATA—*continued.*

KEUPER MARL—*continued.*	Depth bored.		Total depth from surface.	
	Ft.	Ins.	Ft.	Ins.
Red sandy marl with blue spots, very jointy ...	8	3	238	1
Red and blue sandy marl with gypsum	5	0	243	1
Red sandy marl with spots of blue and gypsum ...	12	6	255	7
Red and blue sandy marl with gypsum	8	6	264	1
Red sandy marl with spots of blue and gypsum ...	12	9	276	10
Do. do.	22	11	299	9
Do. do. and gypsum ...	6	4	306	1
Red and blue sandy marl with gypsum, jointy ...	17	8	323	9
Gypsum	0	9	324	6
Red sandy marl with blue spots, jointy	11	10	336	4
Do. with gypsum	3	10	340	2
Do. with blue spots and gypsum ...	1	8	341	10
Do. do. do. jointy...	7	6	349	4
Do. do. do. ...	10	1	359	5
Gypsum	2	0	361	5
Red sandy marl with blue spots and gypsum ...	22	11	384	4
Do. with gypsum	14	6	398	10
Grey shale with markings and streaks of red marl	10	6	409	4
Red sandy marl, blue spots and gypsum ...	9	3	418	7
Do. do. do. ...	58	5	477	0
Do. do. do. ...	33	7	510	7
Grey sandy shale	1	0	511	7
Red sandy marl with blue spots and gypsum ...	16	3	527	10
Do. do. do. ...	30	9	558	7
Red marl with blue streaks and gypsum, rotten ...	5	5	564	0
Red and blue marl and gypsum	10	6	574	6
Do. do.	14	6	589	0
Red sandy marl with blue streaks and gypsum and "loughs" or sparry cavities ...	3	6	592	6
Do. with gypsum and do.	2	3	594	9
Blue sandy marl with gypsum	2	4	597	1
Red and blue sandy marl and gypsum with cavities	2	3	599	4
Do. marl do. do. ...	5	0	604	4
Gypsum and blue and red marl mixed with breccia, and cavities ...	3	10	608	2
Red and blue sandy marl with breccia and gypsum and CRYSTALS OF SALT ...	3	0	611	2
Red and blue sandy marl with gypsum, very jointy and broken ...	13	3	624	5
Do. do. do.	1	0	625	5
Do. do. do. very broken	2	8	628	1
Grey and red marly sandstone	2	10	630	11
Red and grey sandy marl	1	6	632	5
Red and blue do. very broken	5	3	637	8

RECORD OF STRATA—*continued.*

	Depth bored.		Total depth from surface.	
KEUPER MARL—*continued.*	Ft.	Ins.	Ft.	Ins.
Red and blue sandy marl with grey sandstone bands, very broken ...	7	6	645	2
Grey and red sandy marl, very broken	1	4	646	6
Do. do. with beds of grey sandstone and ROCK SALT ...	2	2	648	8
Grey sandstone with steaks of red and blue marl, broken and jointy ...	5	6	654	2
Red and blue sandy marl with ROCK SALT, do. ...	2	0	656	2
Grey sandstone with red and blue marl, very broken	8	0	664	2
Red and blue sandy marl, very broken	3	6	667	8
Red sandy marl with blue spots, veins of gypsum and ROCK SALT ...	7	9	675	5
Do. with veins of gypsum and ROCK SALT ...	4	8	680	1
Do. with blue spots, gypsum and ROCK SALT ...	18	0	698	1
Do. do. do. and ROCK SALT ...	9	3	707	4
Do. do. do. ROCK SALT and nodules of grey shale ...	4	3	711	7
Red and blue sandy marl with ROCK SALT joint ...	1	9	713	4
Do. do. do. and nodules of grey shale ...	6	0	719	4
Red and blue marl with gypsum	10	9	730	1
Do. do. and nodules of grey shale, broken ...	3	8	733	9
Red marl with spots of blue and gypsum ...	4	0	737	9
Red and blue marl with veins of gypsum, broken and jointy ...	9	0	746	9
Red marl with veins of gypsum, broken and jointy	1	4	748	1
Red and blue marl do.	4	8	752	9
Red sandy marl with blue spots and gypsum, broken and jointy ...	3	6	756	3
Do. do. do. ...	51	10	808	1
Do. do. do. broken and jointy ...	11	0	819	1
Do. do. and veins of gypsum	12	10	831	11
Do. do. do. ...	22	1	854	0
Blue sandy marl	1	4	855	4
Red sandy marl with blue spots and veins of gypsum	1	5	856	9
Do. do. do. jointy	20	0	876	9
Do. do. do. ..	7	0	883	9
Do. do. do. ...	12	3	896	0
Red and blue sandy marl with veins of gypsum ...	11	10	907	10
Red sandy marl with blue spots and do. ...	11	8	919	6
Do. do. and thin veins of gypsum ..	24	1	943	7

SALT GROUND.

RECORD OF STRATA—*continued.*

	Depth bored.		Total depth from surface	
KEUPER MARL—*continued.*	Ft.	Ins.	Ft.	Ins.
Blue marl with gypsum	0	9	944	4
Blue sandy marl with gypsum	1	2	945	6
Red sandy marl with blue spots and gypsum ...	13	1	958	7
Do. do. do. ...	40	3	998	10
Do. with blue streaks and gypsum ...	6	0	1004	10
Red and blue sandy marl with gypsum	21	5	1026	3
Red sandy marl with blue spots and gypsum ...	9	3	1035	6
Do. do. do. ...	3	0	1038	6
Red and blue sandy marl with gypsum	21	9	1060	3
Do. do. do.	8	11	1069	2
Red sandy marl with blue spots and gypsum ...	56	4	1125	6
Do. do. do. ...	63	0	1188	6
Do. do. do. ...	34	2	1222	8
Red and blue sandy marl and do. ...	21	6	1244	2
Do. do. do. ...	31	0	1275	2
GREY SANDSTONE, BRECCIA, AND CONGLOMERATE (No. 2 OF MR. USSHER).				
Red and blue marly sandstone	2	10	1278	0
Red sandstone	1	0	1279	0
Red and grey marly sandstone with gypsum ...	43	2	1322	2
Do. do. do. ...	5	2	1327	4
Do. do. do. ...	2	10	1330	2
Red sandy marl with bands of grey sandstone and gypsum ...	1	6	1331	8
Grey and red sandstone	4	0	1335	8
Red and grey marly sandstone with gypsum ...	10	0	1345	8
Red sandy marl with bands of grey sandstone and gypsum ...	20	9	1366	5
Red and grey marly sandstone with gypsum ...	11	6	1377	11
Red and grey sandy marl	0	9	1378	8
Grey sandstone	1	3	1379	11
Red and grey sandy marl	2	2	1382	1
Red and grey marly sandstone	10	2	1392	3
Do. do.	12	0	1404	3
Do. do. strong, with spots of gypsum	5	7	1409	10
Do. do	7	0	1416	10
Conglomerate, fine	1	0	1417	10
Red and grey marly sandstone	16	7	1434	5
Red sandy marl with blue spots and bands of grey sandstone ...	11	4	1445	9
Red and grey marly sandstone	9	6	1455	3
Grey sandstone	0	10	1456	1

RECORD OF STRATA—*continued.*

	Depth bored.		Total depth from surface.	
GREY SANDSTONE, ETC.—*continued.*				
	Ft.	Ins.	Ft.	Ins.
Red marly sandstone	7	9	1463	10
Red sandy marl with bands of grey sandstone ...	3	0	1466	10
Do. with spots of blue	11	0	1477	10
CONGLOMERATE (SUPPOSED No. 3 BUNTER PEBBLE BED OF MR. USSHER).				
Grey and red marly sandstone, strong, with bands of conglomerate ...	9	6	1487	4
Grey sandstone with conglomerate	2	8	1490	0
(?) LOWER SANDSTONES OR PERMIAN (No. 5 OF MR. USSHER).				
Red marly sandstone	42	4	1532	4
Do.	47	3	1579	7
Red sandy marl with grey spots	6	0	1585	7
Red marly sandstone with grey spots	1	3	1586	10
Do. with blue spots	70	5	1657	3
Do. do.	30	2	1687	5
Do. with grey spots	21	1	1708	6
Do. do.	44	9	1753	3
Do. do.	39	2	1792	5
Do. do.	31	2	1823	7
Red sandy marl do.	5	3	1828	10
Red marly sandstone do.	18	2	1847	0
Do. do.	7	6	1854	6
Do.	40	0	1894	6
Do.	51	8	1946	2
Do.	4	8	1950	10
Red sandy marl	1	6	1952	4
Red marly sandstone	22	8	1975	0
Red sandy marl	2	10	1977	10
Red marly sandstone	5	2	1983	0
Do.	55	9	2038	9
Red sandy marl with blue spots	10	0	2048	9
Red marly sandstone do.	23	7	2072	4

(Boring stopped 24th November, 1910).