clude in my abstract. When the boilers of steam-ships are being cleaned, procure portions of the calcareous deposits scaled off the interior, and by treating them in the usual way with nitro-muriatic acid, *Diatomacean*-forms and *Polycystina*-shells may be detected in considerable quantity.

By obtaining these deposits from ships plying within known limits, a series of free floating *Diatomaceæ* might be secured which would afford good data for the ascertainment of their range, distribution, and limits. And so, heartily thanking Dr. Wallich for this crumb of friendly feeling, I close his pamphlet. The year that has just departed has thrown no light of equal importance on geological history; though it has been a very notable year in geological science—notable in the importance of its discoveries, thoughtfully made, and carefully introduced; and beyond measure notable in its crop of theories, and in the agitations produced by them. But of these latter "helps to knowledge" we have surely had enough. Dr. Wallich has sent the ball rolling in another direction; and his labours are more clearly reflected in the mirror of Truth than is any attempt to claim creative power for the working of secondary principles.

A CHRISTMAS LECTURE ON "COAL."

By J. W. Salter, F.G.S.

Not a great many years ago the "bigwigs" in England were assembled in conclave, and the *élite* of science was called before them. There were a great many lumps of a blackish-brown substance on the table, and a great deal of smelling, and burning, and poking of the same black lumps by the same "bigwigs" and learned men. It was the great "Torbane Hill Coal" case.

> "The point was in question, as all the world knows,
> To what the said substances ought to belong."

Was it pure carbon? Was it carbonaceous shale? Was it shale without much carbon? Was it carbon without much shale? Was it bituminous shale? Was it coal-shale? Was it cannel? Was it coal?

We are afraid to say how many guineas were spent, or how many microscopes were busy in London and Edinburgh. But after all the question was simply this, "What is coal?" We are not going to try to give a definition; but if we can show our young readers (and there are, we hope, a good many of them) a few of the facts connected with the structure, contents, mode of formation, &c., of a coal-field, perhaps we may be able to answer the formidable query, "What is coal?" without calling in the aid of counsel, and our fee is—one shilling. As this is a Christmas lecture for our young friends, we hope our senior readers will not take it amiss if elementary phrases are introduced, and a few woodcuts given to illustrate what they know very well.* And perhaps we may be allowed to speak in the first person singular; it is more conversational.

First, then, where is coal found, and how? Of course we all know it is a mineral substance, bedded deep in the bowels of Old Mother Earth. And I need not tell most of you that Old England has more of it than any other European nation; that she is much dependent on it for all her industry; that it has helped to make her peaceful conquests over half the world. And some of you may perhaps know that she is now so tired of using it in this way, that she is going to make a present of one-half of it to her dear friend France—for purposes of war!

A glance at some of the places celebrated for coal will perhaps be the best way to learn the mode of its occurrence. Let us take for instance a place where they send our best coals *from*, but where *it is no use to send coals to.* The Newcastle district is perhaps, all things considered, the richest in England. The river Tyne, rising, as many decent rivers do, in the pure air of the Cheviots, waters all the central parts of Northumberland, and enters the sea at Tynemouth, with far less unsullied purity than it left the mountains with. It is saying much for the traffic on its banks, that the Tyne is nearly as black as the Thames before it reaches the sea. This traffic is wholly in coal.

The Tyne cuts its way through the very heart of the coal-field; the flourishing towns of Hexham, Gateshead, and Newcastle being some of those which dot its banks, while Tynemouth and Shields are the grand ports for its black produce. Get out your map of England if you please, as we shall have further occasion to refer to it. And now I think of it, the little map, coloured by Sir Roderick Murchison, and published by the Society for the Diffusion of Useful Knowledge, is the best we can have, for it has both map and geology all in one.†

Well, we are on the banks of Tyne, looking at the never-ending chimneys and coal-engines. The river is full of collier-brigs; and at the ports there are the long high jetties for embarking coal, and the blazing coke-heaps on the wharves, for the black diamond is not only life but light to Newcastle.

* And it must be understood that we are not going over again the same ground which Prof. Buckman took in the first volume of this work. He was showing us how to search for coal, *this* is for those who know very little about it.

† Stanford's, Charing Cross. Price 5s.

Last, not least, there are the iron furnaces; for in England, happy England, coal is always found in company with iron—the objects of industry with the means of employing industry; the material, and wherewith to work it up; two of the great civilizers of mankind hand in hand. Coal cannot live without iron, and assuredly iron cannot get on without coal.

I will now just sketch the outlines of this coal-field, and you can follow me on the map. You see it is of a long shape, skirting the sea-board from a point a little south of Alnwick, and, passing by Morpeth, it swells out to its greatest width on the Tyne; then crosses the Derwentwater, runs past Durham and Bishops Auckland, till it reaches the Tees, not so very far from Barnard Castle and Rokeby. Here it sweeps round to the east, and gives that classic region a wide berth. Scott would never have thought of laying the scene of Rokeby among barges and chimneys; and I doubt whether Bertram would have proposed to swim the Tees, had it been choked with coal-dust. The loves of Redmond and Matilda, too—well, let that pass.

From Shields southward you will perceive that the coal-field does not actually reach the sea. There is a narrow strip of Magnesian Limestone runs all along the sea border, and the most familiar coal-ports, Monkwearmouth, Sunderland, Hartlepool, are not *on* the coal. However, Walls End, from which in our simplicity we think all our coals come, is actually on the coal. I have been told, however, that there is sometimes more Walls End (that is, brick-bats) in my coal-cellar than I had ever supposed.

I do not know if the number of coal-pits in this magnificent field is accurately estimated. They employed over forty thousand men some years back. The deepest pits are where you might expect them—about the middle of the coal-basin, north of Durham. Some of these are of great depth indeed; one thousand six hundred or one thousand eight hundred feet does not look very much on paper, but if we try to measure it by means of the highest buildings we are acquainted with, we shall understand its enormous depth better. In the north part of the field, three hundred to five hundred feet is nearer the mark.

I shall here recommend to anyone who wants to know more about coal and coal-pits than we can tell them in this short lecture to buy a little work by the Rev. F. Leifchild, called "Our Coals and Coal Pits." I suppose there are very few persons who might not profit by it, and few young ones who would not be merry over it. It may have some errors; what work has not? but it is full of useful and pleasantly told information.

And now, that we may understand clearly what a coal-field is, we must give a sketch of a coal-basin, such as is usually found in Britain. You may turn back to vol. i., p. 188, to see another section by Prof. Buckman: his will not, however, do for our purpose, and we shall refer to the one on the opposite page now and again.

If we were to walk along the banks of the Tyne, however, we should only see about half the basin, as far as *g* for instance; the remainder is hid beneath the sea. But even that half will show the beds in the same order or succession. The Mountain Limestone is a fine rock, and forms most of the high moory ground on the west. Many a border skirmish has been fought upon the heather that

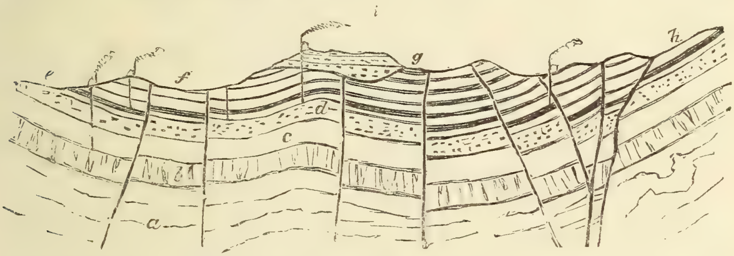


Fig. 1.—Ideal Section of a Coal Basin, to show the usual arrangement of the Beds, and the Dislocations caused by Faults.

a, Old Red Sandstone; *b*, Carboniferous or Mountain Limestone; *c*, Millstone Grit; *d*, Farewell Rock, sandstone chiefly; *e*, *f*, *g*, *h*, coal seams, or beds, the layers of coal from one foot to ten feet thick, and with shafts piercing two, three, or more of the beds, as the case may be; *i*, Magnesian Limestone and Red Sandstone, unconformable on the Coal-beds.

covers its surface; and many a bold moss-trooper has ridden for dear life across the bogs that ornament this formation,* and the one succeeding, viz., Millstone Grit.

It should be noticed that the "Millstone Grit" is all or nearly all sandstone—sometimes clayey, but more often hard; and the lower part of the coal-formation itself is nearly all sandstone, with a few bands of clay or shale. But as we rise higher in the beds, the clay grows more and more, the sandstone still being present in large quantity, till shale, as it is called, often makes up the chief part of the beds. Under every seam of coal, with scarcely an exception, lies a bed of what is called fire-clay, a rather hard clay, which makes excellent linings for stoves and furnaces, and which besides is used for crucibles and other purposes. Of this clay more by-and-bye, when we come to speak of how coal is formed.

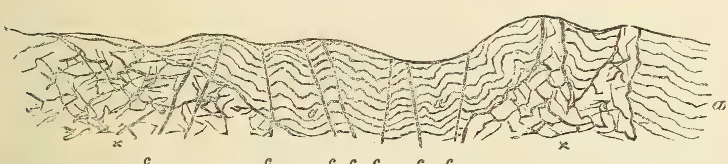


Fig. 2.—Ideal Section showing Granite and Killas (soft slate), with Metalliferous Veins.
*, granite; *a*, killas; *c*, *c*, *c*, metal veins.

And now it will be seen from our diagram, and from what has

* "He rode a small but hardy nag,
That o'er a bog—from hag to hag—
Could bound like any Bilhope stag."

been said, that coal is always found in layers and beds, not in veins, as metals are. If you compare the following sketch of a mining country with the coal-field above given, you will see the difference at once. This difference is of the greatest importance in mining for coal, as we shall see by-and-bye, but we must not wander from our point at present.

I have only run over one of the coal-fields of Britain yet, and not quite the largest. There is the Whitehaven coal-field, which supplies all Lancashire, and which has galleries far beneath the sea. The great Yorkshire coal-field is one of our busiest manufacturing districts. We may well say that, when we remember that Bradford, Leeds, and Halifax are the very heart of the cloth trade. This important field runs down in a long strip to Nottinghamshire, passing by Doncaster and Mansfield. It includes nearly one thousand square miles, and it is really larger than this, for they have been trying of late to find coal beneath the Magnesian Limestone to the east of it. The Duke of Newcastle has lately sunk shafts, and profitably too, through the limestone and the red rock beneath, and then pierced the coal, and got plenty of it.

Now the Yorkshire coal-field runs down (see the map) all the eastern side of Derbyshire, outside the Mountain Limestone of that beautiful tract. On its west side runs the Lancashire coal before-mentioned. Thus both sweep round the limestone like a mourning cloak thrown over the shoulders; and here again we see the close connection of Mountain Limestone, Millstone Grit, and Coal.

The little tract called the South Staffordshire coal-field is a rich, nay, for the size the richest of all our coal-fields. Except one in Nova Scotia, this little coal-field contains the very thickest seam of the invaluable mineral known in the whole world, for the "Thick Coal" of Staffordshire is thirty feet. And I believe more iron, is got here than in any other district of the same area. The Dudley and Wolverhampton ironmasters are the princes of the trade, though South Wales is treading closely on their heels. I need only mention that five million tons are raised per annum in this district—worth a million and a quarter pounds sterling.

There are the smaller fields of Ashby de la Zouch; the Tamworth coal-field, with its beds thrown up in nearly a vertical position; the Bewdley or Forest of Wyre; Shrewsbury; Lee Botwood; Clee Hills; all little patches, which once no doubt were joined together. But the restless sea swept over them, and since they have been raised into dry land, the breakers have beaten against their coasts till they have left us only shreds and patches of what was once a continuous coal-field in mid England.

Then there is the Flint coal-field, which keeps the North Welshmen warm. It ranges from the sea near Chester to Oswestry, on the borders of Shropshire, and, in conjunction with the lead-works in the limestone (Mountain Limestone again you perceive) which, runs all the way along its edge, keeps a large population busy. It does one's heart good, when going into Wales for a holiday (and you are always kept waiting at the Llangollen Road Station), to turn for a while and look over this busy coal-field perched high on its limestone terrace. Don't give all your attention to the mountains, but think of the labour that is going on around you, amid those hundred chimneys and in that dingy atmosphere ; and reflect, too that the picturesque scenery on your left is, like much else that is beautiful, only for holiday wear, while the hard work on your right is the true condition of our life if we would attain the useful.

Then if we take the train to Bristol, we shall find another small but productive coal-field, thoroughly well worked, and for its area very rich. It has been computed to contain six thousand millions of tons. If they could only get it all! It supplies one and a-quarter millions annually. Across the Severn is the Forest of Dean, an oval mass of high ground, rich in coal and iron. It was one of the earliest places where iron was worked; and the old rude furnaces are still occasionally discovered. There are twenty to thirty seams of coal here; and if you want to see what a coal-field really is, on a small scale, look at the model by Sopwith of this district. It is in the Museum of Practical Geology, Jermyn-street ; and you may know more about a coal-field in an hour by consulting it than by reading this lecture for double the time.

Now we are near the great South Wales coal-field, or coal-basin, as it is better called ; a mighty mountain mass that runs for seventy miles from Monmouth to Pembroke. Across its width, from Swansea to Merthyr, it measures full twenty-five miles. Its area is computed at one thousand nine hundred and forty-five square miles, and its production is enormous. Nearly all our steam-coals come from thence ; and there it is that those wonderful furnace-coals, called anthracite, are found. If you draw a line across the field from north to south—from Swansea to Merthyr—you will find that all on the west side is anthracite, or stone-coal, and all on the east bituminous, or caking coal*—very nearly so. There are, of course, some exceptions to this remarkable rule, for which I really can give you no good reason. It is supposed that deep-seated volcanic matter has acted on the western half; but we see no trace on the surface of this. The fact is certain, nevertheless, and a very curious fact it is. Those who have had occasion to travel along the network of railways which run among these hills will know that the coal crops out, as it is termed (that is, shows itself), along the sides of the hill in seams. It does not hide itself here in deep underground workings, but is sometimes even wrought out in the face of day as a quarry, more often obtained by levels into the heart of the mountain, in the way they work for metals. And they have such abundance of water-power, that when compelled to raise coal from greater depths, they can often employ what are called lifts, or balances (cisterns which are alternately filled with water or coal), and so make the water itself lift the coal out.

* For an excellent short description of this field by Dr. G. P. Bevan, the reader may turn to vol. i. of this work, p. 126, &c.

Add to all these natural advantages a very large supply of coal important for Government use, some very intelligent masters and overseers, cheap labour, and easy access along the valleys* to the ports, and you will not wonder that South Wales should be prosperous. There is an Institute for Engineers specially for this coal-field; and he must be a second-rate man who cannot realize his £800 or £1,000 a-year at least by the charge of a set of works. Many of the owners are extremely wealthy, and hospitable too. And somewhere on the northern crop I visited a friend, who is at once magistrate of his district, lieutenant of a rifle corps, surgeon of a large work, organist, lecturer, a good geologist, and a kind man.

The north and south borders are called respectively the north and south crops. Along the northern edge the strata lie pretty flat, or gently inclined. They rest upon the terrace of Millstone Grit and the Mountain Limestone precipices overhanging the red sandstone country of Crickhowel and Abergavenny.

On the southern crop the beds of rock lie at a steep angle, and again from beneath them come out the Millstone Grit and Mountain Limestone of Oxwich and the Mumbles; or, further west, the great limestone cliffs of Tenby, which of all places is *the* place to study Mountain Limestone, Old Red Sandstone, and contorted coal-strata.

There is one more coal-field in Britain, but a poor one, the culm-measures of Devon, only worked for local use; and it is more than probable that these culms are coal-beds in the Millstone Grit series. For in Scotland, of which we have not yet said anything, and where the richest seams are found, not only in their proper beds, *above* the Millstone Grit, but *in* it and all *through* it. Nay, it does not stop here, for in the Lothians and Fifeshire, as indeed is the case in Northumberland, there are coals and coal-shale among the beds of Mountain Limestone, thin layers of this black fuel lying under mountain masses of the limestone rock; and here and there are coal sandstones, rippled and worm-marked, showing the action of large lakes, or, much more probably, of the tides on the surface only just before occupied by a coal forest.

Nor is this all, for deeper still, and far below the Mountain Limestone, the Scotch coal-beds lie in the Lower Carboniferous strata. The celebrated Burdie House beds of coal and limestone are among these.

The great quarries of coal sandstone around Edinburgh, from which their fine building stones have been quarried, lie far below the lowest level of the Mountain Limestone. There is a charming little work—the "Story of a Boulder," told by Archibald Geikie, that gives a clear notion of the Scottish coal-fields in most pleasant and readable style.

And then for Ireland. We might almost write a chapter on the coal of Ireland as short as Swammerdam's famous chapter "On the Rats of Africa"—"There are no rats in Africa," said the naturalist; and it is all but the same in Ireland. True, there is a patch or two

* The Crumlin Viaduct in Taff Vale is a splendid work of art.

at Dungannon, and in Clare and Kilkenny; but the beds are so poor in coal, and the produce altogether is so very small. It would almost seem as if Providence had made amends for the scanty supply, and indicated the direction Ireland's industry should take, by covering her fertile limestone plains with the exhaustless peat. Peat is the Irishman's friend, and like the seal to the Greenlander, supplies him with light, warmth, and even building-materials; and now they are manufacturing peat, it will be meat and drink to the Irish peasant.

We have seen *how* coal is found, and *where* in Britain; how it lies there in beds or basins, not in veins or bunches; how it occurs mainly in the great Palæozoic formation, above or about the geologic place of the Mountain Limestone. And this is true for nearly all of Europe, and of the mighty coal-fields of America. But it is not the case over the whole world. Even in our own country there are coal-beds in our oolite rocks, above even the New Red Sandstone; and in Yorkshire these rocks are neither few nor barren.

This "oolitic" coal is the common coal of Virginia, in the United States. A similar coal forms our staple supply in the East Indies. We have oolitic coal at Natal and along a great part of southern Africa. Australia is supplied with oolitic coal. Wherever Englishmen found a colony, there is coal; but it is not all of the same age. Borneo is not yet ours, but there is coal.

And there is tertiary coal. Our own little coal-field at Bovey Tracey, Devonshire, is a miniature representative of much larger brown-coal fields in Germany. The Miocene coal of the Rhine is little better than a fossil peat;—sticks, and leaves, and fruits, and here and there an insect, a fish, a frog, are found in this freshwater coal. If a fox got drowned in these old swamps, he, too, turns up as coal for German firesides. Nothing comes amiss. Some varieties of this tertiary coal are little else than pond confervæ matted close together, and layers of such like peaty matter form the dysoile, or "paper coal."

So there is every transition in mineral composition from the peat bog to the coal-bed; and it is not anticipating our next lecture to say that all coal, of whatever kind or value, is vegetable produce. It would be out of place to doubt that our youngest readers know this fact; what we propose to do next time is to give a short account of the methods of extracting these precious black diamonds; to show what kinds of vegetables produced our great coal-fields; and to discuss briefly the valuable services we receive from "Coal."

(To be continued.)

on the descendants of the parent type, although it would not be possible for me fully to subscribe to Darwin's theory—which I do not perfectly realise, without much further examination and reflection —still there is so much truth in many of his views and statements regarding "The struggle for existence" and "principle of natural selection," that the subject has full claim to a calm and dispassionate examination, and may lead us by degrees to the better understanding of many problems relating to species and their origin than we at present possess.

A CHRISTMAS LECTURE ON "COAL."

By J. W. Salter, F.G.S.

(Continued from page 13.*)*

In our last lecture stress was laid on the fact that coal-beds, unlike mineral veins, are stratified—not injected, or filling cracks in the earth as metals do. And when we use the term stratified, we mean that the materials we are considering—coal, ironstone, sandstone, clay, shale—were all deposited sheet over sheet, layer over layer, principally by the agency of water.

In scarcely any other way, except by water, can we conceive of materials being spread abroad over vast surfaces, in that even and regular manner which we call "stratified." As a rule, the matters ejected from the mouths of fiery volcanos are only rudely heaped up, and unless they fall into the sea, do not undergo this smoothing, spreading-out process. The sand of the sea-shore however, and the pebbles on its margin, and the mud of its great depths, are truly "stratified;" and if a fertile plain, or a marshy district were submerged in the waters, the materials on that surface would be soon covered over by the ooze and sand and shingle, and would then be said to be "interstratified" with them. In this way coal-beds occur among beds of sandstone and other rocks.

It is seldom that any coal-field contains more than twenty-five or thirty workable seams: and perhaps these altogether do not amount to above eighty or one hundred feet at the utmost, while in South Wales the coal *strata* are twelve thousand feet thick. The mass, you see, is rock.

The miners have names for all the other beds, or "measures" as they term them. Some of them are amusing, In Staffordshire, for instance, the beds of sandstone (once loose sand) receive the names of White, grey, green, and blue rock; Rough rock; and "Peldon." This last is a very common term.

The clays or shales are more oddly named — Clunch; Ground; Partings; Binds; Clod; Shale; Pouncil batt; Table batt; Pricking and Blacktry.

Ironstone beds rejoice in the appellations—Pennystone; Brownstone; Whitery; Lambstone; Blue flats; Cakes; Grains; Gubbins; Ballstone; Bindstone; Silver thread; Diamonds; Getting rock; and "Poor Robins."

The bad coals are—Bass; Smutt; Black bazil, &c. And every coal bed has its name too. There are the—Top four-foot coal; Yard coal; Brook coal: Robin's; Flying reed; Deep coal; Mealy grey coal; White coal! Stone coal; Shallow coal; Old-man's coal; "Heathen" coal; Stinking coal; Bazils; Slipper coal; Sawyer coal; and Bottom coal.

I'm sure that is enough. Moreover, every district has its own vocabulary. Only fancy what the Welsh must be!

But whatever be the kind of bed *over* the coal there is one invariable rule *below* it. A bed of clay, called "fire clay"—a fine soft substance useful for furnace-pots and furnace-bricks—occurs beneath every seam. Sir William Logan, now at the head of the Geological Survey in Canada, first found this out in Wales. It is the clue to the history of coal; and we shall have to refer to it again.

Please to bear in mind that these layers or beds of coal are remarkably regular. It is of the greatest consequence in mining that they are so. If you find, for instance, that the Old Man's Coal is always next to the "Heathen" Coal, and the "white coal" comes next (I don't know that they do), you are safe for the whole coal-field. You have only to measure the distance between the Old Man and the Heathen, and so on, and you know whereabouts to expect them in any other part of the field.

We have reason to believe too that every bed of coal and ironstone has some peculiarity in its fossil contents; and if this should turn out to be true, we shall have a still better means of ascertaining in what part of a coal basin our pits may be sunk—a very important point—for if our mines should happen to lie upon the lowest beds of the whole series, (say at *h*, in the woodcut, p. 9,) it would be a rather unprofitable investment to buy ground there. But if on the contrary, we are likely to be on the "Top coal," why then, work away merrily; we may say, altering Mrs. Hemans' sense, but not her words,—

> "Yet more—the depths have more;—what wealth untold
> Far down, and shining in their stillness lies,"

I will not add another line—for geology does not admit of parodies, and good sense refuses them.

Well, now, we've found our coal. The next thing is to get it. England requires for home consumption and for export nearly seventy million tons per annum; and if you put all her coal-fields together they do but measure nine or ten thousand square miles. Yet by good? management we contrive to get that enormous quantity annually from them. On an average coal fetches nine shillings a ton. So that here is thirty million pounds sterling, and more. Besides we raise four million tons of iron. Each costs about a penny a mile per ton carriage by the railway. And where carts are used, a shilling a mile per ton must be paid for them.* Coal and Iron together would pay two-thirds of our taxes for the year!

America is richer in coal than we are; she has twelve times as many square miles of coal-beds. But her forests are yet so extensive, that she does not—including British America—find it necessary to raise above seven millions of tons a year. This is scarcely so much as France gets from her scanty coal seams. All honour to her genius and industry (would they were always employed in arts of peace); she gets seven and a half millions from about one thousand eight hundred square miles of coal. But what shall we say of little Belgium, which raises eight millions out of her five hundred square miles! Belgium has plenty of iron too, and she *makes* muskets, but does not wish to *use* them.

Russia will scarcely tell us much about her coal-mines. She gets less than a million tons per annum! Austria is almost equally poor; and the whole of Germany does not raise much above five millions.

England has very nearly three thousand collieries in profitable work, and four government inspectors to see that they are safely handled.

As the beds in a coal basin, though regular, are often much broken, it is usual to bore the ground before commencing the operations for extracting it. The boring apparatus is very simple. It consists of a gigantic gimlet, which from its weight also acts as a chopper or a chisel. It is made of iron, tipped with steel; and of joints which screw together as they are successively pushed down — the point being either a cork-screw or scoop for soft strata, clay, &c., or a chisel for harder rock. The principal instrument in use is called a "wimble." It consists of a steel cylinder, or rather a plate of steel rolled round into a cylindrical shape, but so that the edges overlap a little; and it is found that this curled-up plate, with a square notch cut out of the sharp-edged end, is about the best form for the double work of chiselling the stratum and bringing up the fragments. Then there is a scoop for mud called a sludger; and a great many varieties which may be screwed on to the end of the rod. But the main end and object of all, is to cut the beds through, one after the other, and bring up such fragments to the surface as shall show the nature of the ground through which the rod passes. The instrument is worked by four men when the depth is not very great; but horse or even steam-power must be used in deep borings; and the work is very expensive, since the rod must be continually drawn up and the fragments removed. For eight hundred feet down they can tell very accurately what beds they are passing through.

* My friend, Mr. Robert Hunt, supplied me with these facts about our coal consumption.

All this is only preliminary: there must be a door to your house if you are to get into it, and the shaft is the door to a coal mine. This is the first thing to be completed. It must go the whole depth of the mine, in order that they may get rid of the water that soaks through the strata. This is man's great enemy when he is mining—at least the first one—for bad air is at least as great an enemy afterwards.

The shaft then is sunk to the "dip" end of the main, or lowest level of the floor, in order that all the water which may percolate into the workings may eventually flow down into the "sump" or cistern that lies at the bottom of this "engine shaft."

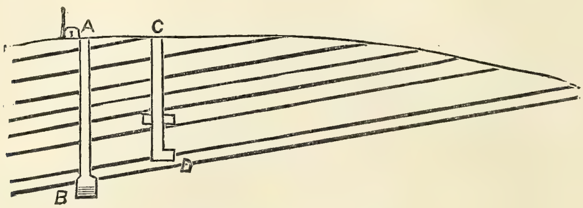


Fig. 3.—Diagram of Shafts,
a b, engine shaft,—*b*, the "sump," or cistern; *c*, upcast shaft,—*d*, its furnace.

It is no light work to sink a shaft—eleven or twelve feet wide—to a depth of perhaps one thousand feet. The materials are sometimes very soft, as shale; but this has the disadvantage that you must line it with brick or wood throughout. Sometimes the rock is hard enough to stand alone; then the matrix is a tough rock and very difficult to cut. Oftentimes the leaky state of the bed makes it necessary to line it with wooden "tubbing" throughout; and this is an old custom. More recently it has been found advantageous to use iron cylinders the whole way! A shaft a thousand feet deep will ordinarily cost about three thousand pounds; and if a two hundred and fifty horse-power engine be required, there is another five thousand pounds to begin with; and while on the subject of expense, it may be well to say at once that fifty thousand to two hundred thousand pounds are no uncommon sums required to set a colliery fairly going, before a bucket of coal is drawn. But then if it yields—and it ought to yield—twelve per cent., it is no bad speculation after all.

They generally find too they must sink two shafts; and the pumping engine will not do for drawing also. The two shafts are required for ventilation; and they serve also to prevent the mischief of letting everything down and drawing everything up the engine pit. We will leave the ventilation alone just now; and only say with reference to the engine that the quantity of water required to be removed is often enormous.

The way in which water finds its way into a coal pit is the same as that in which it finds its way into Artesian wells. The water comes from the surface, *a, a,* runs down the porous strata, till it comes to the bottom of the basin, and there finds its own level. It will not run through the clay *(b),* and hence you have only to drain what lies above it in the strata, *a.* Nay more, if one part of the basin be cut

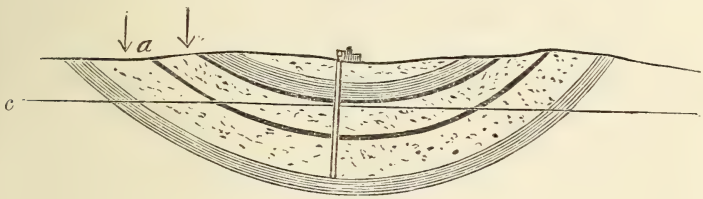


Fig. 4.—Section of Coal Basin.
a, porous beds; *b*, clay; *c*, water level.

off from the rest by faults, as in our diagram, p. 9, only what lies on its own side of the fault will have to be drained by any shaft. So that a fault is a positive advantage, paradoxical as it may sound.

Though they cut up, and often tumble the beds much, yet being filled with clay, they effectually shut off the water of one compartment from the other; and render it possible to work in the dry, when otherwise you would have to work in the wet. Like many other apparent disadvantages, they do good after all.

We may guess what a terrible plague the water is to the miner, when we know that in sinking some shafts, the engine has had to draw off three thousand gallons a minute, with a pump eighteen inches diameter. It is still worse in the Cornish tin mines.

It is a curious fact that in deep mines the water is generally salt—often salter than the sea. It often, too, contains green vitriol (sulphate of iron) iodine, bromine, and other constituents of sea-water, which no doubt it once was. We shall see that by and bye.

And now we've got our shaft down to the lowest point—our pumps at work—nearly all our money spent; and we have to find out how to work the pit to the best advantage: for some pits will send up three hundred or four hundred tons a day; and an acre of coal with sixteen thousand tons in it may be cleared off, by a good method of working, in six weeks!

The winding engine or "whimsey" is not nearly so powerful as the pumping engine—seldom one hundred horse power—and round the drum over the pit's mouth are coiled the flat chains (of three or four links,) or strong ropes, which last they find best for drawing coal.

The baskets or "skips" are of various shapes in different mines. A common form, which strikes a stranger with some surprise, is a low flat box on wheels, on which the coal is piled; and when the pile is high enough, a broad iron hoop is thrown over it; more coal is added; other hoops thrown over that—till the pile is as high as can be raised with safety. The hoops effectually prevent the coal from falling off; but it has an odd appearance, like a black crinoline petticoat.

Suppose then the miner at the bottom of his shaft, it is not all straight forward digging then. There is a structure in coal, and he must take advantage of it. It is full of joints which cut it up into squarish pieces; one set being backs or cutters, and the other joints; and the art is to drive the pickaxe and lever along these two sets so as to work the coal in the easiest directions.

This structure can be seen even in the little specimens in our own coal scuttles, and is due to the pressure the coal has received since it was hardened. There is nothing crystalline about it, as some have fancied. It is a sort of cleavage.

As most coal lies on a slope, the first gallery is driven horizontally along it at the lowest level, *a*, *a*. This horizontal gallery, which must

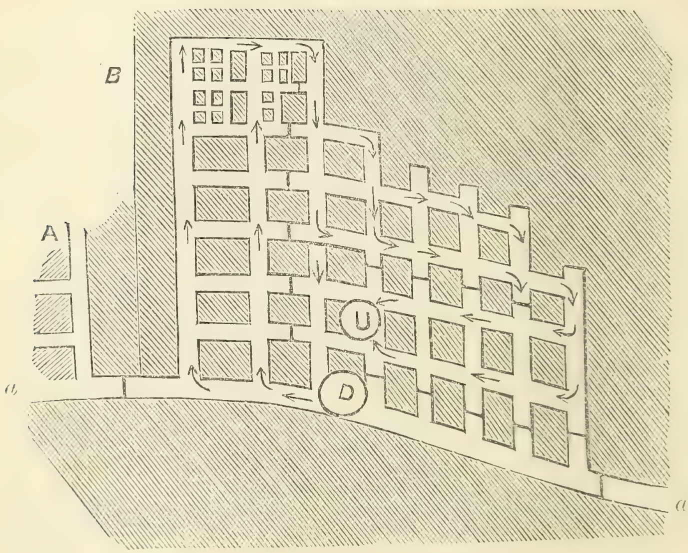


Fig. 5.—Plan of Mine-workings.

follow the curves of the strata, if there be any, is called the "dip-head level;" from this they drive galleries *upwards*, (the coal is brought much easier down than up) from *a*, *a*, to A and B in our plan, and cut cross ones at right angles—keeping all at quite regular distances; and so proceeding forwards and sideways, in squares, to the extent of their working, or of such portions as they choose to work out first. The galleries made by the hewers are called "stalls"; the pillars of coal left between are called "posts"; and the usual mode of working is to go over the whole space in this way, leaving posts large enough to support the roof, and gradually driving the galleries or stalls forward, up the slope of the mine.

The coals are brought down the galleries, which have each a tramway laid in it, in small wheeled cars, which either carry the skips or are themselves detached from the train, hauled up, returned empty, and again wheeled up by the "putters," or boys employed for this purpose. Ponies generally draw the loaded cars in lines along the diphead level to the mouth of the drawing shaft; and these ponies, sleek and well-fed, live in the warm mine and like it. They learn to hold their heads low, for there is never too much space in a coal gallery; and if we would imitate them, we should escape many bumps through life.

When all the galleries are cut, then they begin to thin the "posts"—and this is a work of some little danger. Not only is the roof inclined to come down on the miners' heads, but the floor often bulges up beneath their feet. Such a disturbance of the ground, arising from the great pressure above, which forces down the pillars into the clay beneath, is called a "creep." It has an odd effect on the buildings over the colliery. They begin to fall sideways out of the perpendicular; square windows take a lozenge shape; doors, &c. will not open, being jammed at one corner. Ceilings fall, bit by bit, upon the inmates; and altogether a "creep" produces unpleasant feelings for all concerned. But it cannot be helped—the black stores below are worth more than the buildings above; and, therefore, they must go the way of all buildings.

The process of thinning may begin at one corner, *a*, (the furthest from the shaft,) before all the galleries are finished; and when a good many of the "posts" are thinned as much as they will bear, they extract even these, substituting wooden posts for coal ones. The space then looks like a forest of dead props, among which you may easily lose your way; and, as these decay, down comes the whole mass, slowly but surely, till the roof and floor meet in a broken irregular mass. The hollow space with its ruin of shale and sandstone—of sound and decaying props, is then shut off from the other compartments of the mine. No ventilation is further given to that quarter, called a "goaf," and foul gas and tar-water, and every abomination, may collect there till time shall end. It is a sort of Tophet.

There is another way of working, much used in thin seams and small collieries, and universally preferred in Scotland. It is "long wall" working. In this method the galleries are driven (as before from a dip head level) parallel to one another the full extent of the mine, but not near together, and the coal between the ways is then worked out bodily;—small entries being made through the wall, and all the intermediate coal "got" out, enough only is left along the sides of the ways to ensue the safety of the latter.

Our diagram shows a piece of this sort of work. (*See p.* 66).

The rubbish, (roof, floor, &c.,) which must be got out in the main ways with the fuel in thin seams of coal or ironstone, (for ironstone is got in almost every coal pit,) need not be taken away; but is filled into the empty spaces, *b*, as the coal is extracted. And a sort of bed is thus made to receive the descending roof. It is stifling work in these thin seams when the poor hewers have to lie on their sides and ply their picks against the black wall in face of them, with a yellow

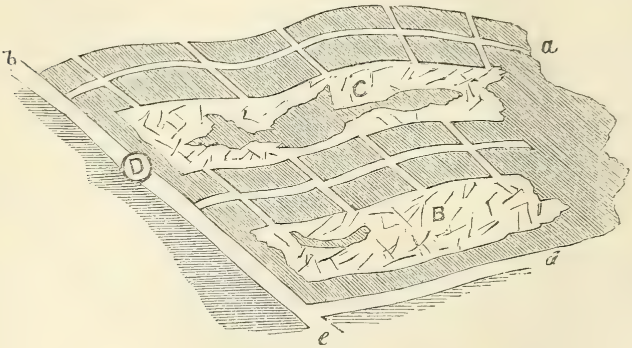


Fig. 6.—Plan of worked-out Mine.
a, the galleries with their walls of solid coal; *B, C*, the "goafs," or worked-out spaces filled with shale and rubbish; *D*, shaft; *b e*, dip-head level.

candle flaring in the one hand, (or a Davy,) the elbow resting in a hole cut to receive it, and the whole man sweating in a hot atmosphere for hours together. It is a heavy price to pay for comfort above ground. But they do not murmur; and a good hewer will clear eighteen shillings a week, after paying for his candles, tools, &c.; while the overmen receive twenty-five to thirty shillings.

The thick coal of Staffordshire was formerly mined on the "pillar and stall" system; and Mr. Warington Smyth has given a graphic picture of a "side of work in the 'thick seam,' when a large fall of coal is brought down from the dusky heights of that lofty chamber. The thunder of the falling masses, which seem to shake the solid earth, contrasts fearfully with the dead silence that ensues. The hardy colliers scarce break it by a whisper, while in suspense they listen for the slightest crack which might portend a further fall." But the enormous height of this coal-chamber, often thirty feet, was of itself a source of danger; and the pillars required, and which must be all waste, so large, that it is now found profitable to work it in "long-wall" method, a half or more of the seam at a time, beginning at the top. By this means they get all or nearly all the coal—about thirty thousand tons to an acre. They used to get but sixteen thousand. There are four hundred and twenty collieries in this district alone. About one third of the coal they raise is expended in their furnaces; (for near a million tons of ironstone are raised in this field annually, besides the coal formerly mentioned, page 10). About half as much is sent from other places; and a year or two back this quantity produced six hundred thousand tons of pig-iron from sixty-four furnaces. There are one hundred and two mills and forges in the Staffordshire district. For this information, also, I am indebted to Mr. Robert Hunt, of the Mining Record Office.

We are not talking, however, of Staffordshire, but of coal mining in general, and now a word on the ventilation—the most important of all things for a mine after the water has been expelled.

Without a furnace to create an upward draught in the one shaft, so that the air may rush down the other and travel through the mine, the work would be well nigh impossible. The way this precious air is made to circulate throughout, instead of merely going from one pit to another, is partly explained by our diagram, fig. 5, p. 64. The arrows point the way the air goes up one side of the workings, round the further end, along the working faces of all the galleries, and then back again nearly to the same point to the upcast shaft, *U*. There the contaminated air, after passing the mouth of the burning fiery furnace, gains the upper world, and makes room for a better and purer element. The air is restricted to this course by the air-doors, which are marked as black lines in our plan, across the galleries. These are strongly framed doors, of iron chiefly, and are kept by boys, "trappers," as they are called, whose sole and solitary work it is to open and shut these trap doors whenever a train of waggons passes. A few words of converse with the "putter" lads, who bring the loaded skips down the "ways"—or it may be, quite as likely, a scuffle with them—are the only relief these poor boys have (they are mostly very young) during the dark and solitary hours. They cannot afford a "low" or candle for the "trapper" boys!

In most of the important mines, a separate "windway" or "airhead" is driven by the side of the galleries (or an air-tight wooden tube is carried along), exclusively devoted to air from the downcast shaft; and then, after supplying the miners in the stalls, finds its way back along the galleries, escaping every time an airdoor is opened. The same method is adopted in longwall work. But occasionally, as I learn from Mr. Smyth, they work two galleries side by side; and use one of these for the incoming air, and the other for the return draught. Whichever mode is adopted, the principle is the same, viz.: to carry the air all round the mine, drawing it forcibly down one shaft and up another, at the other end of the system. Be it remembered the actual heat of the earth is much greater below the surface than above; that choke-damp (an elegant term for carbonic acid) and other poisons too sometimes, are present in the mine; and ventilation, whether by fans or furnaces, will be seen to be vital to the work.

Any neglect in this important matter exposes the miners not only to the displeasure of the overseers, and the ill report of the government inspector, but to the positive danger of explosion from the foul gas, which is ever accumulating in the mine. The fearful fire-damp, which has played so terrible a part of late, is generated rapidly in the coal pit. It is carburetted hydrogen, the same gas which burns harmlessly in our streets. It rushes out from many a fissure and dark chamber upon the miner, who, in spite of all the precautions taken for his safety, often ventures on his work with a naked candle, instead of the useful instrument which Davy and Stephenson had given him.

I need not speak of this "wonderful lamp," which lights to treasures as valuable and far more durable than those Aladdin found. Who would have thought, when Davy was pondering on the fact, that flame did not pass readily through narrow tubes—and trying shorter and shorter lengths of these in philosophic sport—that he was really making a discovery which has saved the lives of thousands.

The government inspection, now regularily carried on, will do much to encourage those that do, and shame those managers that do not conform to the regulations laid down for their benefit. But more, a great deal more is be looked for from the education of the miners and their children. They have friends for the body, and for the mind too; and a life spent underground cannot kill out the intelligence and virtue of a man who is determined to hold it fast.

And now we have done with coal for the present, let us try and find out how it was formed.

It is perfectly understood that it is made up of plants. We need not enter again into that proof: coal is full of them. You cannot stand five minutes by the side of a shaft, and look at the heaps of dark blue shale brought out of it, without finding them full of fern-leaves, and grass-like plants, and bits of diapered or fluted cylinders highly ornamented; with occasional fir-cones, or what look like them, and a heap of other fragments. The coal itself bears witness to the quantity of plants in and about it. It is generally too solid—too crystalline so to speak—to show its structure well. But here and there the charcoal fragments in it are covered with vegetable tissue, and the microscope reveals still further traces. Of these I will say a little more in our next number, for my space and time too are somewhat limited at present; and with the fact that plants in myriads are found *in* the coal, *above* the coal, and *under* the coal, I must request my young readers to be contented till next month.

(To be Continued.)

ON SOME NEW FACTS IN RELATION TO THE SECTION OF THE CLIFF AT MUNDESLEY, NORFOLK.*

By Joseph Prestwich, F.R.S., F.G.S.

In the fine coast section extending from Happisburg to Weybourne, the Boulder clay is laid open to an extent nowhere else equalled in England. The relation of this Boulder clay, on the one side, to the Forest bed and Crag underneath, and, on the other, to the series of

* Read before the Meeting of the British Association at Oxford, in June, 1860, and published by permission of the Author.

A LECTURE ON "COAL."

By J. W. Salter, F.G.S.

(*Continued from page* 68.)

We finished last month with the fact that plant-remains were found in plenty both above and below the coal. I shall draw your attention first to the roof-shale—or clay over the coal—"over-clay" as it is often called: for in this the great majority of remains are preserved.

In the roof-shale two kinds of plants are the most conspicuous—fern-leaves, and the diapered cylinders mentioned in our last. These are the prevailing fossils, though there are a great many besides.

Looking first at the fern-leaves, which from their beautiful forms cannot fail to strike the observer's eye, one is surprised to notice the extremely perfect state in which they occur. Delicate fronds, spread out as for the sheets of an herbarium, with hardly a leaflet disturbed from its true place, crowd the roof-shales of nearly all coal-mines. Dr. Buckland sang the praises of this beautiful tracery, which covers the roof of the mine, in glowing strains such as it will not do for a plain geologist to imitate. I have a lurking suspicion, however, that the great doctor conceived the passage not *in* the mine, but *out* of it.

Fig. 6.—Portion of a frond of *Alethopteris* (*Pecopteris*) *lonchitica*.—Brong.

At least one hundred and twenty species are known in our British coal-strata. So perfect are they occasionally, that the little fruit-patches (*sori*, as botanists term them), are found upon the backs of the fronds. This is not very common, except in one kind—the *Pecopteris*, which happens to be more abundant than most of the others, and in some species of this the fruit is found. There is a specimen in the Museum of Practical Geology which shows these little seed-patches. It is from the Forest of Dean; and Mr. G. Roberts has shown me several, and given me some from the coal-field of Bewdley Forest. We shall give a figure of this fruit in our next number.

Some ferns, nay, many of them remind us closely of the tree-ferns familiar in our hot-houses; others resemble the humble

* Those who really wish to know more about coal-plants than this little sketch will give them, should read the article on coal in the new edition of Mantell's "Wonders of Geology." By T. Rupert Jones, Esq., of the Geol. Society.

fern-fronds of our lanes and hedge rows. But all are perfect. It is rare to find a disturbed or crumpled leaf, though of course they are often only fragments, such as our brooks and rivers float down.

I am writing for the younger readers still, or otherwise this sort of lecture would have no business in a scientific periodical, and I shall not, therefore, burden your memories with a number of Latin terms, which would be very intelligible to students, such as I hope you may all one day be. However, coal-ferns have not received christian or surnames such as our wild ferns rejoice in. Lady fern and Rock-brakes, Black Maiden-hair and Moonwort, are a great deal easier to remember than *Neuropteris Scheuchzerii*, and *Alethopteris lonchitidis*. *Pecopteris plumosa* is not such a hard sounding word; *Pecopteris Miltonii* and *P. muricata* are both tolerable. But it so happens that some of our common coal-favourites, like favourite children, have very long and unpronounceable names. Yet we do not like either the less for that.

All those I have mentioned above are well-known fossils: all of them are found on the continent as well as in England; and one or two of them are to be picked up at every coal-pit. The pretty *Alethopteris lonchitica* may be obtained in the nodules of ironstone in Shropshire, and large slabs of it come from Durham. It is sometimes known under another name, *Pecopteris lonchitica*, but the above is the true one.

Fig. 7.—*Alethopteris (or Pecopteris) Serlii.* Brongniart.—Reduced size.

We have represented only a single "pinna" of the plant, for in its perfect state it looks a good deal like our common heath-fern, *Pteris aquilina*. The *P. plumosa* is like the Lady-fern. *P. loreopteridis*, a strong-leaved fern, with a thick stalk or rhachis, a good deal resembles the *Lastrea*, and so on.

There is a beautiful fern common near Bristol, the *Alethopteris Serlii*, which has fine large leaflets like the *Polypody* except that it is a compound leaf (vipinnate) instead of a simple one. There are larger ferns still—the species of *Neuropteris* as they are called, which rival in size our tropic species. But these, numerous as they are, and common too, for there are as many of them as of the genus above quoted, are not quite so often met with. They too, though very rarely, show the fruit on the under side of the leaflets.

There are the delicate *Sphenopteris*, whose leaves are of all shapes and sizes, agreeing in nothing so much as the particularly slender and narrow shape of the leaflets and branches. They look like parsley leaves, coriander leaves, mimosa, and some again look like what they are — finely divided ferns. Figure 7* shows the peculiarly graceful character of the tribe. There are several other kinds of "*opteris*", with which, as the Scotch song says, "I'm laith to vex ye." But I must mention one that is not very common in the coal, but which has been found in a perfect state in some beds older than the coal, both in Ireland and in Scotland. This is the *Adiantites Hibernicus*, a fern first brought to notice by that eminent man and ardent naturalist, Edward Forbes. It is common in some rich fossil beds in the upper part of the Old Red Sandstone of Ireland. It puts one in mind of the fern which is the glory of Killarney—the King or Royal-fern, *Osmunda regalis*—about the same size, and with the spreading broad leaflets set on a broad stem. But whereas our Killarney friend carries her fruit on her head, that is to say, the terminal leaves and pinnæ are changed into fruit-bearing spikes, the fern that grew in old old times on the margin of the Palæozoic bogs has its lower or bottom pinnæ crowded with seeds.

(To be continued.)

ON THE DISTRIBUTION OF CEPHALASPIS AND PTERASPIS IN ENGLAND.

BY GEORGE E. ROBERTS.

I HOPE our scientific tourists of the approaching season will take their good eyes into Herefordshire quarries. For now that the Scotch monopoly of the Old Red fishes is broken up, they will be found to repay time and trouble, if searched for in that and the adjoining counties; and something like a reasonable history of these strange old littoral fishes may be the result of a single season's work. There is a great deal about them well worth knowing, and their remains will be found tolerably abundant, though very fragmentary, both in the sandstones and cornstones; and therefore I have a peculiar pleasure in introducing our primæval fish-fauna to the notice of those on search already—or hoping to be as the season advances—for relics of ancient life.

Before I call particular attention to some fruitful localities, let me say a few words upon the physical condition and geographical aspect of the age they lived in. Though I ought rather to say ages, for they anticipated the advent of the system they are popularly said to belong to—that vast life-era—the extent of whose inland-seas and shallow littoral ocean-zone we see in the sandy, shaly, and gravelly beds which contain *our fishes*, and of whose deep seas the thick-bedded

* The figures of *Sphenopteris Schlotheimii*, *Adiantites Hibernicus*, and *Osmunda regalis* will be given in the next number.

THE GEOLOGIST.

APRIL, 1861.

A LECTURE ON "COAL."

By J. W. Salter, F.G.S.

(Continued from page 102.*)*

In many respects the plants and animals of the coal differ much from forms now living. It is probable that the greater part of them are even of different groups or families from the existing ones. But the ferns at least show strong traces of affinity. Here and there we meet with the young fern-leaves coiled up as they now lie on the heather, ready to unfold on the return of spring. We all know these "Bishops'

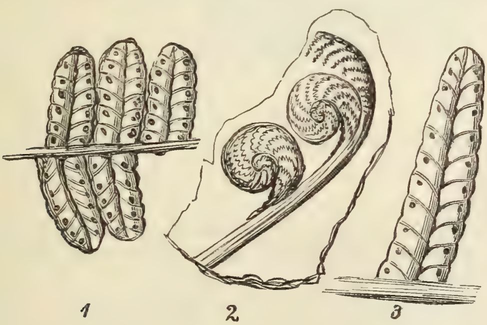


Fig. 1.—1. Curled up fronds (circinate) of Pecopteris (Brongniart).
2. 3, Fructification of ditto.

crooks" that nestle in the bottom of the fern-baskets; and when I saw a grand specimen in Mrs. Stackhouse Acton's cabinet (it now graces our museum in Jermyn Street), with the delicate coil of pinnæ, every leaflet in its place, I almost leaped for joy. It was from the Le Botwood coal-field. There is one figured in this work, vol. iii, p. 460 (but the finder has not yet been told, I think, what his fossil is): it is from South Wales, and a beautiful specimen.

Fig. 2.—*Sphenopteris Schlotheimii,* a coal-fern from Strasbourg.

Our space was too crowded last month to give the necessary figures of the ferns; and it is but limited now. The leaves or fronds of the delicate *Sphenopteris*, mentioned p. 101, are very abundant. There are a number of species. *S. elegans*, *S. crassa*, and especially *S. affinis* occur in the lower coals, beneath the mountain limestone of Scotland;—*S. artemisiæfolia*, *S. Honinghausi*, *S. linearis*, *S. trifoliata*, are all characteristic of our upper coals, and the two last are found in France and Germany. Our figure represents the *Sp. Schlotheimii* of Brongniart, a plant that is found in the coal shales of Strasbourg.

The *Adiantites* of the Old Red Sandstone, mentioned last month, will be figured, and full descriptions given of it by the officers of the Irish Geological Survey; it is only, therefore, needful to give a sketch

Fig. 3.—Osmunda regalis, living at Killarney. To show the terminal fructificatfon of the living fern.

Fig. 4.—Adiantites Hibernicus, fossil in Kilkenny. To show the lateral spikes of fructification in the fossil.

figure of it here, especially as it does not actually belong to the coal, though the same genus is found there. We must now pass on from the ferns, and speak of the cylindrical stems so common in the coal.

The other plants of the coal, which strike us most, are the fluted stems called *Sigillaria*. They abound in all the shales, with every kind of varying proportion in the patterns, which nevertheless is of a regular and definite kind. It consists of longitudinal flutings, generally in right lines, sometimes a little zigzag; and on the surface of the flutings are scars, either round or somewhat kidney-shaped, or hexagonal—or even double ovals—or purse-shaped, narrower above than below, and always with a couple of dots in them, which are the marks of the vessels that supplied the leaves. For the scars are the bases of the leaves, which are seldom found; they are of a long shape, with a rib down the middle. The stems vary from a few inches broad to three feet in circumference, and specimens have been found that must once have been sixty feet long. They are generally quite flat in the shale, and often broken to pieces; and they are, most generally, covered with a coat of coal. The scars outside the coal-envelope are not quite the same as those which show within, but pretty nearly so. Our figure shows this (Fig. 5).

The Sigillaria was a tall tree, with a bare trunk regularly pitted by the leaf-scars. It branched at the summit, and bore long narrow leaves, as above said; its fruit is not known. Its internal structure has been examined in some very perfect specimens, by foreign and English botanists (fossil-botanists as some folks call them),—Brongniart, Hooker, Dawson, and others. It is a good deal like the *Cycas*, known in our green-houses as a Cape plant, but in some respects more like Ferns. Nor is there any living family of plants which tallies with it, though in a rough way it has been supposed by good judges to belong to the great tribe Coniferæ—to which our fir-trees, pines, cedars, and junipers belong. Hooker regards it as nearer the club-mosses, and especially near to *Lepidodendron*.

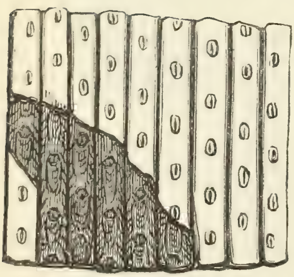


Fig. 5.—Sigillaria.—Internal cast of stem, with portions of the bark, carbonised.

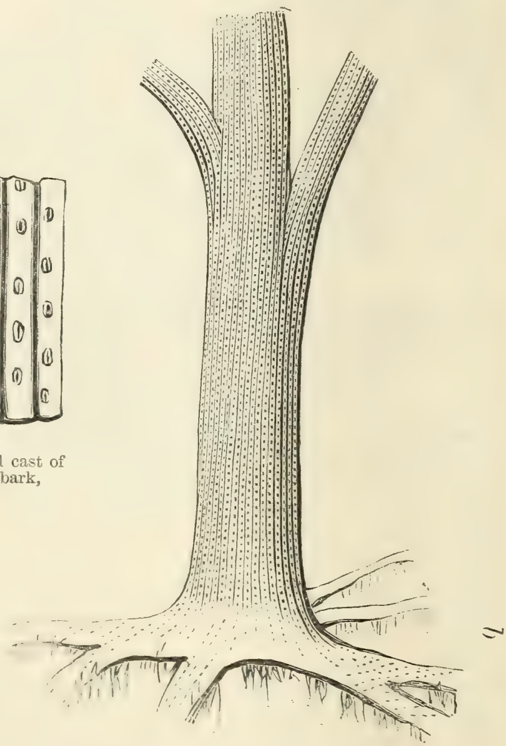


Fig. 6.—Sigillaria—the common coal-tree. Stem, perhaps 15 feet high: with its roots Stigmaria) *b*.

The patterns on the bark differ in all the species, of which no less than fifteen are known in England alone. We have figured two of the more remarkable; and really they might be used for paperhangings in the studio of the geologist. Who will try copies from nature for this purpose?

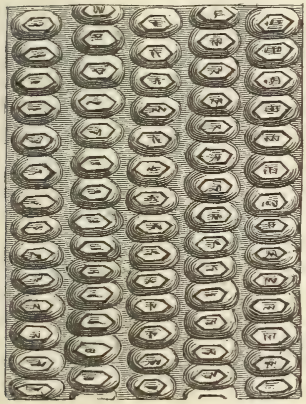


Fig. 7.—Sigillaria elegans.
Patterns of bark Sigillaria.

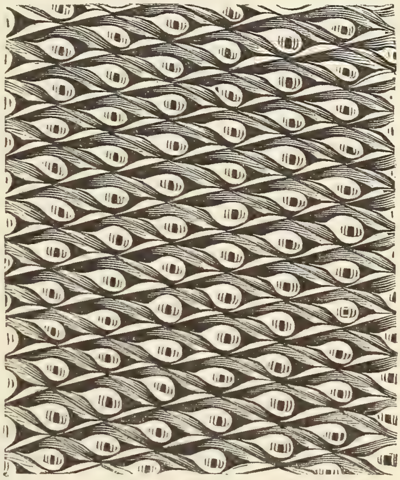


Fig. 8.—Sigillaria Defrancii.
Pattern of the markings on the bark.

But Sigillaria is not always found lying prostrate. It is very often upright, as it grew; so many instances are known of this that it is almost useless to repeat them. A stump, ten feet high, is figured in Dr. Mantell's "Wonders,"* a book worthy of every young geologist's ambition. Others have been noticed by Sir Charles Lyell, and a whole forest of short stumps was discovered in 1838, near Chesterfield, during the diggings for a railway. There were no less than forty trees—a few feet apart—on this one spot. In Durham, at Newcastle, and in the South Wales coal-basin, others have been found. Hugh Miller, in his interesting book—"First Impressions of England and the English," (p. 233)—has described his visit to the celebrated Wolverhampton coal-forest. Here seventy-three stumps, in three tiers, one over another, are closely packed: and three successive forests—on the same spot—seemed to him the best way of accounting for it. I think we have a better explanation; but I am not sure of that.

But, then, these trees have roots to them; and the discovery of these roots has opened up a new chapter in the history of coal. Nay, it has deciphered that history; for till Sir W. Logan found that every coal-bed had its underclay full of roots, and till Mr. W. E. Binney, of Manchester, traced these roots (which are called Stigmaria, (fig.), to their connection with the tree, we never truly knew how coal was formed.

2nd Edition.—By T. Rupert Jones, Esq., Vice-Sec. Geol. Society, 1858.

I ought to have said however, that the bark of the *Sigillaria* is in general the only part preserved. There was within it only a soft tissue of cells, with a central stem or axis of wood, the latter occupying but a small part of the cylinder. The soft tissue easily disappeared while fossilizing, or even before the tree fell, for we often find the stump filled with sand, and broken fragments of vegetables mixed within it. In one or two trees of this kind in the sandstone beds of Nova Scotia, Professor Dawson and Sir C. Lyell found a whole colony of centipedes or such like things, with snails and lizards! We must see how this happened when we come to the mode in which coal was deposited. The clay beneath the coal called an "underclay" just as the roof-shale is called "overclay"—is, as I have said, full of plants. These are the Stigmariæ, and our figure above shows what they are like. Now the great importance of Sir William's discovery was this,—that the only fossil found in the clay is, with the rarest exception, the Stigmaria; and it is invariably present. The fire-clay as it is called, is generally a pure sediment: and close upon it lies the coal, as pure coal as the other is clay. Now if we want to know what plant the coal is made of, we must certainly ask the underclay where the roots grew; for there, if anywhere, we shall get an answer. Here Mr. Binney's discovery comes into play, for if Stigmaria is the root of Sigillaria—and is universal in the fire-clay—then, of course, Sigillaria is universal in the coal.

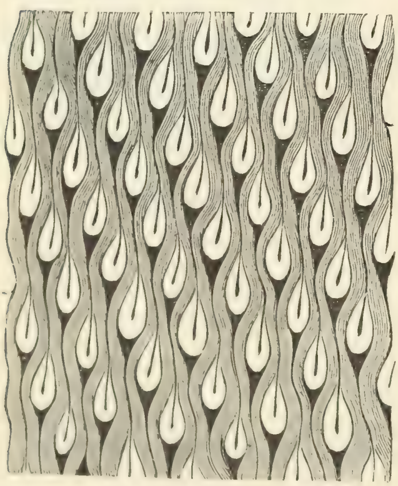


Fig. 9.—Pattern of bark (Lepidodendron).

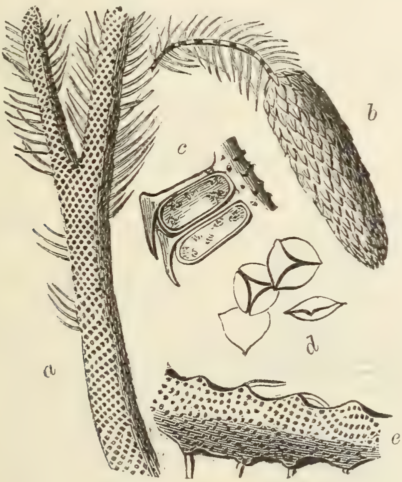
We have seen, too, that fragments of the *Sigillaria* trees are among the commonest in the shale that lies *above* the coal-bed. In truth the trees were higher than the depth of the coal-seam. Thus we may easily conceive that the roots of a tree may be *below* the coal—which is seldom above a few feet thick—the lower part of its stump fairly *in* the coal, and its bole and branches all *above*.

Thus it is we find the flattened stems, and thinner branches and leaves, so often in the roof shale.

There is another tree, *Lepidodendron*, whose roots we do not certainly know, but which appears to have grown in the underclay. It is almost as common as *Sigillaria*, and nearly as large. Perfect specimens have been found, forty feet in length from the soil to the end of the branches. But of course it is the rarest of things to meet with such trees.

Lepidodendron differed from Sigillaria in the arrangement of the leaf-scars, which pack closely in quincunx fashion over the surface. Our sketch shows this. The patterns are equally beautiful and as applicable to pictorial design as in the other case. The diamond shape of the scars will help you easily to recognise fragments.

There are many species of these trees. The commonest of all I think is the *L. Sternbergii*, of which a full length figure is to be found in the revised edition of Dr. Mantell's excellent book—"Jones's Wonders," as it ought to be called—p. 749. I have only given you fragments of branches, stems, leaves, fruit cones and their seeds or



Stem *(a)*, and leaves, catkin (*b*), seed-vessels (*c*), and seeds or spores *(d)* of Lepidodendron. We have added *(e)* its supposed root Halonia.

spores. It is well known now that Lepidostrobus *(b)* is the fruit or catkin of Lepidodendron. The little mountain club-moss, which rears its yellow catkins amid the sheltering boughs of the heather,—its stem clothed with long scale-like leaves,—is the best representative, in England at least, of these old giant forms, as large as forest-trees, which abounded so greatly in the times of the coal.

There is yet another plant, so very common in coal-shales, that it ought to be mentioned separately. I mean the *Calamites*. We have not space for a figure, and refer you to the book above quoted, p. 736, where the plant is, however, drawn upside down in fig. 3—quite right in figs 1 and 2. The look of these plants is so much that of the horsetail (Equisetum) of our ditches, that it is no wonder ordinary fossil-hunters should take them for blood-relations.

* And I have added the *Halonia*, which I fully believe to be the root of Lepidodendron.

Yet this plant was probably nearer to the great trees above-mentioned than anything else we can mention. The stem (or rather pith, for we do not see the stem itself in one case out of a hundred, but only the cast of the pith) is ribbed, and jointed just like Equisetum stems, but very rarely shows any leaves. Its leaves and branches were probably the plants called *Asterophyllites* and *Sphenophyllum*, and they look much like the "goose-grass" with which as schoolboys we used to bleed our tongues in sport. These two are very common. Some have broader leaves than others, and an American author of repute (Dr. Shumard, I believe) has seen reason to think that they were aquatic plants—that the broad leaves were the floating leaves, and the narrow ones the leaves that grew beneath the water. The common white buttercup which looks so gay in spring time on the ponds will serve to illustrate this supposition. Others do not think it quite a true one. To show how near some of these *Calamites* approach to the structure of ferns, I give here two cross sections, one of a tree fern, taken from Brongniart's work (Fig. 11), the other of the plant of a Calamite family (Fig. 12), figured by Dr.

Fig. 11.—Section of tree fern, showing the large bundles of vessels.

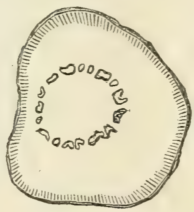


Fig. 12.—Section of one of the Calamite tribe, showing the smaller bundles of vessels surrounding the pith.

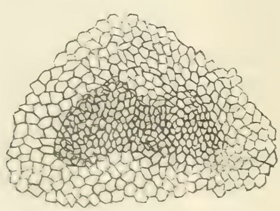


Fig. 13.—Portion of cross section magnified.

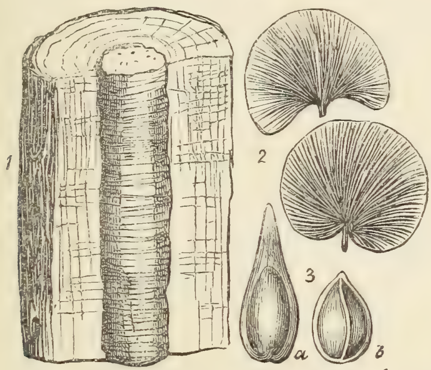
Unger, in a work on the fossil plants of Saxony. Fig 3 shows a portion of one of these cross sections magnified, the bundle of vessels among the cellular tissue.

Now then, for some real solid wooded trees—and with these we must finish—for the coal-flora after all was a scanty one compared with living nature. The individuals were abundant enough, but they were of comparatively few families of plants.

Fir trees of one sort or another were abundant in the coal-period, and have been so in every succeeding formation. But here, as in every other case, the coal-trees were different from the modern ones. Now we have abundant spruce, and larch, and fir; junipers, and cypress trees, and yews; and in the tertiary and oolitic times these were common trees. But the *Araucaria* tribe, to which the graceful Norfolk Island pine belongs, is only to be met with rarely. At least it is confined to a small portion of the globe. In the coal time it was the prevailing form. There is no need to give a drawing of the structure of this wood, for it has been given by every author who has written on the coal.

Wood is made up long fibres, which fibres communicate with each other by pores. The wood of coniferous trees is specially remarkable for the large disks which surround these pores. They are disposed in straight rows, and most of the *Coniferæ* have only a single row. But the *Araucariæ* have a double row—or more than a double row; and all the coal fir-trees are of this kind.

Again there is a remarkable difference between the coal-trees and their living representatives. In no living fir-tree does the pith show of any size, except in quite the young shoots. After that age it gradually diminishes in diameter, or rather does not increase with the growth of the tree, being pressed upon by the successive layers of the



Coniferous wood (Dadoxylon), with its pith, Sterubergia leaves (Cyclopteris), probably of the same coniferous tree; fruit and seeds (Trigonocarpum) of the same.

wood, till in a cross cut of a piece of fir a mere trace of this substance, so important in the first stages of the young branch, is to be seen. The case is different with the old fir-trees of the coal. Here (according to the excellent observations of Dr. Williamson, of Manchester), the pith is of enormous size, and retains that size during the after-stages of growth, if it does not actually increase. It was long ago known under the name of *Sternbergia*, and is often as thick as a large man's thumb, or even thicker. I have seen some as thick as a child's wrist.

Dr. Williamson found that this pith was imbedded in a wood which was in all respects a true fir-tree, and which has been known under the name of *Dadoxylon*. It is not certain that all the firs belonged to this one genus; most probably they did not. At all events Dadoxylon is a very common coal-fossil.

Here then we have the wood and the pith; and let me say that any one who is disposed to examine the contents of his own coal scuttle may do so with advantage, for the charcoal he will find in it shows, under the microscope, a beautiful tissue like that described above. As an opaque object it is very beautiful, and polished slices sometimes show it equally well. Prof. Queckett, of the College of Surgeons, has distinguished himself for his researches into these tissues, and in the wonderful "Torbane Hill case," referred to in the opening of this lecture, his skill was largely called into requisition.

But having got the wood, one naturally wishes to find the leaves and seeds. What were they?

Some years back a suspicion entered my mind that the leaves commonly called *Cyclopteris* might belong to this family of trees. It is true they might be ferns, to which order they have been usually referred. But there are fir-trees, or at least Coniferæ, which have broad leaves very much of the shape of these supposed ferns. Heart-shaped or fan-shaped leaves, with a shorter or longer stalk, and the veins so like that of the fern, that it is difficult to distinguish fragments. These are the *Salisburia*. They are trees well known in our parks and gardens, and there is a noble specimen at Kew. Let anyone compare a figure of the *Cyclopteris* of the coal with a leaf of the living *Salisburia*, and he will be struck with the strong resemblance. The possibility of this has of course occurred to those skilled botanists who have written on coal-plants; but none of them have, I think, been rash enough to call the *Cyclopteris* the leaf of *Dadoxylon*, or to suggest, as I do now, that many of the leaves called *Noggerathia*, and even some called *Adiantites* are nothing more or less than leaves of the coniferous trees, which we know abounded in these old forests.

It is otherwise with the fruit. Professor Henslow some time back showed me the fruit of *Salisburia*, and compared it with the *Trigonocarpon* from the Manchester coal-sandstone. And Dr. Hooker, by a series of original researches into these coal-nuts (published in the Royal Society's Transactions), has demonstrated that they are the fruits or nuts of coniferous trees, each with a large fleshy envelope like the fruit of the yew. Well then, if Dadoxylon is the common fir-wood of the coal, and *Trigonocarpum* the common coal fruit, we need only put two and two together; and if we cannot convince the cautious botanists, I hope I may convince my student readers there is a strong probability that the one is the fruit of the other.

Coal pine-trees; coal pine-leaves, and coal pine-fruit! We are getting on. But this is not quite all. The same distinguished botanist to whom I have so often referred (who has shown us the true structure of the *Lepidodendron* and its seed; and has illustrated the fruit of these old fir-trees), suggested years ago, in the gallery of the Museum of Practical Geology, that the one supposed *flower* of the coal belonged to the fir tribe too.

It is called *Antholites*, and may, as he admits, certainly be what it was at first described to be—the flower spike of a plant not distantly related to the pine apple! There are some prickly leaves (if they be not fern-stalks) in the coal-shales, which render this possible,—not, I think, probable.

Cycadeous Plant (Pterophyllum), from the carboniferous beds of the Altai Mountains.

But on the other hand these so-called flowers have no very regular parts, and are not a bit like any living ones that I know. They look to me, as they did to Dr. Hooker when he first examined them, very like unfolding buds of Coniferæ, with somewhat broader leaves than we are accustomed to see in modern firs or larch, but not broader than many of the yew tribe. As I do not know that the author I have named still holds the original opinion, I do not quote him for it; but only give my own.

Of the Cycas tribe, so abundant in oolitic times, a few representatives occur. They are not characteristic of the coal, and are rare in England. We give a foreign specimen.

And now a few grass-like plants, of whose nature we cannot say much, for want of the fructification, would end the series, had it not been known that they are *fungi* in the coal! I know but little about them, and will therefore say less; but there they are—three species.

Of the animals of the coal I shall have a little to say next month, when I hope to finish this rather lengthy lecture. I am not tired of it myself, but our young readers may be.

THE GEOLOGIST.

MAY, 1861.

A LECTURE ON "COAL."

By J. W. Salter, F.G.S.

(Continued from page 131.)

There is less to be said about the animals found fossil in the coal than about the plants. And for this reason, that the vegetables formed the coal; the shells and crustaceous creatures, and fish, and reptiles, were but visitors: or if they lived upon the spot, bore no larger proportion to the stately jungle that sheltered them, than the denizens of our own forests now-a-days do to the trees and undergrowth which give them food and habitation.

Still, animals are far from rare; and the common ones are chiefly *bivalve shells* and *worms*. The truly land animals are but few. A rare insect or two has been found in our own country. Dr. Mantell discovered the wing of a fly not unlike the dragon-fly, and supposed to belong to the American genus *Corydalis*. This insect is figured in Sir R. I. Murchison's Siluria,* and is now in the British Museum. And one or two beetles, or rather what have been supposed to be beetles, have been found in Coalbrooke Dale. Cockroaches and crickets have left their wings in tolerable plenty in the coal-shales of Saxony.† No doubt they were welcome there amid the coal-solitudes, and put a little life into them. They are far from welcome now. I recommend all who may live in the neighbourhood of the coals to give a little time to hunting for the relics of these old

* 2nd Ed. 1859, p. 321.

† See Dunker and Von Meyer, Palæontographica, vol. iv

insects, &c. They will probably be rewarded by finding some wing-cases of Orthopterous tribes, and it will be their first discovery in Britain.

Arachnida (that is, spiders and scorpions) were probably not rare in the coal-period. A fossil scorpion was found at Prague; and unless I am very much mistaken, I have seen relics of more than one large spider from Coalbrooke Dale, in Shropshire.

In those celebrated trees described by Professor Dawson and Sir Charles Lyell,* and which were found in the sandstone of Nova Scotia, millepedes (*Xylobius*), or at all events some members of the myriapod group, were found. They were associated, in the same hollow stumps, with numerous small land-snails. These were somewhat like the little Pupa, or chrysalis snail, so common on moss-grown trees, in the deep woods of Old England. But I shall never believe that coal-forests were like the woods of our own times, for reasons which will immediately appear.

Fig. 1.— *Pupa vetusta.*

One word, though, about the other land animals found in these trees, for Prof. Dawson in his last communication to the Geological Society,† makes it extremely probable that there were land lizards to feed on and restrain this insect-life within due bounds. They may have been amphibious lizards—the larger species (*Dendrerpeton Acadianum*), found in the coal-measures, certainly was so —yet the nature of the teeth of another (the *Hylonomus*), and its scaly armour, look too much like those of living land lizards, to allow us readily to believe that it too was a Batrachian reptile, modified for and adapted to this sort of life. We must wait for more complete information.

And now, with all these proofs that the creatures of the land lived and died in the old coal-forests, why should we refuse to believe that these grew upon dry land?

That dry land was not far off, I must, of course, admit. The muddy sediment and sand that form the mass of the coal-measures were derived from land; and must have been formed, as sand and mud are now formed, by the washing away of rock and earth—the daily action of the tides and rivers.

But the question is, whether the plants grew on the land, and were then submerged; or whether they grew in the water, and so were mixed with the "spoils of animals, savage and tame," that lived in the water.

The commonest fossil in the coal measures—the one which *par excellence*, is "the coal fossil"—is the *Anthracosia*, or Unio, as it used to be called.

This is a bivalve shell with closed valves, looking not at all unlike the common Unios of our streams, but never showing any of those peculiar wrinkles about the beak, which living *Unios* always exhibit.

* Quart. Journ. Geol. Society, vol. ix., p. 58.
† Ibid. vol. xvi, p. 275.

The hinge, when the valves are opened—they are rarely so—does not present the usual teeth of Unio; but the binding ligament of the hinge has nearly the same position. Moreover, the Unio shell has—besides the scars left by the two great muscles which close the shell—a smaller scar (or even two) next to the front muscles; and this is absent in the fossil. Professor King, of Galway, a close observer of the insides of "auld warld" shells, established this fact, and distinguished the fossil from Unio by means of it. He called the coal-shell *Anthracosia*, a very appropriate and even classical name. I heartily wish all palæontological names were so!

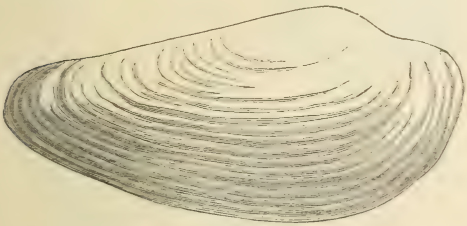


Fig. 2.—*Anthracosia* (Unio) *acuta*, Sowerby.

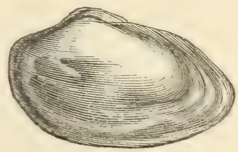


Fig. 3.—*A. ovalis*, Martin,

And I find, on carefully looking over a number of specimens, that every now and then one shows the whole surface of the shell wrinkled, not the beak merely, but the broad surface of the shell itself. This also is a character not found in the true Unio; but is common to all the mud-burrowing tribes of the myadæ or "gapers;" and to this tribe I would refer the shells in question.

The more so, as another shell often accompanies the *Anthracosia*, which clearly belongs to some family of mud-burrowing shells. It has the surface strongly wrinkled; and these wrinkles are of such a shape as to indicate the existence of a rough strong envelope to the tubes of the mantle, like those of the *Mya.* Here is a sketch of the living Mya or "gaper," as it stands head downwards in its muddy home; and side by side with it is the shell I have referred to, called by me *Anthracomya.* These really are the principal shells throughout the greater part of the coal-measures. And, so far as we know, all such shells must have lived in salt-water,—though I am bound to say that an eminent man who has lately written on the shells of the coal of Germany, considers that some of them are like the freshwater muscle *Dreissena.* I do not believe

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Fig. 4.—*Mya truncata*, with its rough tube (Woodward).
Fig. 5.—*Anthracomya senex*, with its tube and foot restored.

it, but I believe he thinks so, and it is a very excellent suggestion—for the shape is very like.*

But in the lower part of the coal-formation, and in one or two beds also in the upper portions, there are none but truly sea-shells. It would take long to enumerate them; but I need only mention one or two familiar names. *Avicula*, or rather a shell between *Avicula*

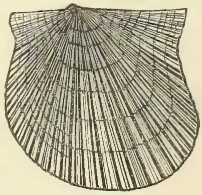

Fig. 6.—*Aviculopecten papyraceus*, Sow.

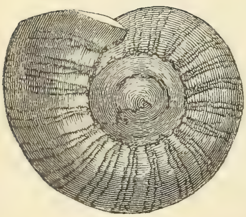

Fig. 7.—*Goniatites Listeri*, Sow.

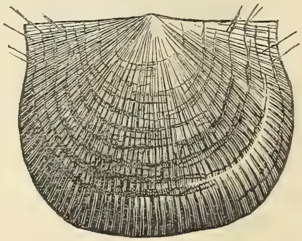

Fig. 8.—*Productus semireticulatus*, Martin.

(the pearl oyster), and *Pecten* (the scallop), and therefore called *Aviculopecten*, fig. 1. *Goniatites*, fig. 2, a shell which is a near relation to the nautilus. The nautilus itself is common enough. *Nucula*, a true sea-shell, is with them; and, to name no more, the *Productus* (fig. 3), which is found everywhere in the mountain limestone, must have been deposited in sea-water—and deep sea, too—for it is found with corals and fish, sea-faus and sea-lilies; and belongs to a group of shells which never quits the open sea.

Perhaps we need not dwell upon the shells any more; suffice it that those of the bottom of the coal-measures are all marine, and those of the top parts are not much like freshwater ones, and from the company they keep, were probably marine too.

* This author, Rudolph Ludwig (Dunker and Meyer's Palæontographica, vol. 8, pl. iv., v.; and vol. 10, pl. lxxi., lxxii.), in his papers on the "Naiades of the Coal Measures of Westphalia," thinks he has detected the freshwater shells *Cyrena*, *Anodon*, *Unio*; all of which are, I believe, *Anthracosia*; and also *Dreissena*, one of which at least is an *Anthracomya*. He also quotes *Planorbis!* but the little shell which goes under this name is the *Spirorbis*, mentioned further on.

For with these shells, and attached to the plants that lie among, and above, and beneath the shell-beds, is found abundantly a little sea-worm, or rather the spiral case of a sea-worm (*Spirorbis*, fig. 4), which is as well known now upon sea-wrack and kelp, as it was upon floating leaves and plant-stems in the coal-period. It is called *Sp. carbonarius* from its habitation in the coal.

Fig. 8.—*Spirorbis carbonarius.*

And there were sea-crabs—not, it is true, like English ones—but like the king-crab (*Limulus*) of American waters. And shrimps though rare, were not quite absent. And sharks swam in the water; for we find their teeth and fin-bones. And other strange uncouth fish, more like the bony pike of America than aught else. This is a freshwater fish, and tells rather against my opinion; but all I can say is, that if the coal-fishes were not saltwater fishes, they had no business among saltwater shells and crustacea, and they must take the consequences.

But how reconcile saltwater and its inhabitants with lofty trees, and a thick jungle, and delicate ferns; and colonies of insects, and spiders, and scorpions, and lizards?

No doubt this is a difficulty. Most authors who have written on the coal have taken it for granted that it must have been formed in mighty swamps at the mouths of rivers, with only frequent access of the sea; with much dry land in the neighbourhood to supply the ferns and firwood, and permit the growth of a thick underwood such as certainly must have formed the coal.

But others, and amongst these I must name Prof. Henry Rogers of America, and our own Mr. Binney chief*, have not shrunk from the supposition that the *Sigillaria* grew on the sea-bed itself.

"Only one particular process," says Prof. Rogers, "promises to explain the occurrence of these thin and uniform sheets of material, of which the thickness is often less than a foot, while their superficial area is many hundred square miles. I cannot conceive any state of the surface but that in which the margin of the sea was occupied by *vast marine savannahs* of some peat-forming plant, growing half-immersed on a horizontal plane, fringed and interspersed with forests of trees, shedding their leaves upon the marsh. Such are the only circumstances under which I can imagine these regularly parallel, thin, widely-extended sheets of carbonaceous matter could have been accumulated."

The smooth surface of the underclay formed a fit nidus for the young plants, and as the deposit went on, they struck their roots far and wide into it, and grew to their full stature. These trees formed the bulk of the coal-forest. The interstices were filled with the reedy plants, Asterophyllites, Calamites, and sedges, with many a Lepidodendron and coniferous tree; and as the decaying leaves and

* Trans. of the Association of American Geologists and Naturalists, 1842, p. 433. Binney, Manch. Geol. Trans. vol. i., p. 172, 1840.

branches fell off in myriads, with fruits, and catkins, and seeds, they formed a matted mass in the sluggish water.

On the stumps of the decaying trees the ferns would grow, and I have seen markings on a *Sigillaria* which induce me to believe this was really the case ; and the hollow trees would form a safe retreat for such wingless insects, snails, or lizards, as the forest possessed.

Lest this should be thought a wholly anomalous state of things, we have, as an instance, the mangrove swamps of tropical countries, where, in the saltwater lagoons, whole forests of trees grow, among whose roots fish and crustacea find protection, and sea-shells are abundant. A species of oyster is commonly attached to the stems and the submerged branches. And if the *Unio* of the coal must be regarded as an *Unio*, there are even kinds of this genus which live in these putrid swamps.

For it must not be supposed that the trees grew in an open sea. Shallow tracts, shut out from the main ocean by spits of sand and sandbanks, and scarcely, if at all, subject to tides, are the state of things that prevail in many a lagoon now; and in all probability such was the case in the coal epoch. In such localities it might be expected that we should find creatures admirably adapted to their habitation, but unlike the ordinary denizens of sea or lake. The quantity of decaying vegetation would give a black colour to the mud, and coal shales are very black indeed: occasional currents would bring sand from seaward, and sandstones are common things in the coal-formation. If the ocean got free entry for a while, we should have colonies of true sea animals (the *Goniatites* and *Avicula* before mentioned), and such do every now and then occur. But the ordinary inhabitants of these delightful muddy creeks, half smothered in a thick forest of water-loving plants, would be the shells and crustacea suited to the locality, *i. e.*, the *Anthracosia* or *Unio* and the *Limulus*. Crowds of minute water-fleas (*Cypris* and *Cythere*), such as live in stagnant waters now, are found in the coal-measures. Thousands of worms, of all sizes, burrowed in the silt, and revelled in the feast of fat things that were putrifying there.

I believe this picture gives the true aspect of the dank and luxuriant vegetation, flourishing in a sullen steaming atmosphere heavy with miasmatous vapours ; uncheered by the song of birds, scarcely musical with the hum of insects, and varied by no flowers, no trees yielding fruit, whose seed was in itself! Such a habitation was not fit for man—not even for the quadrupeds he delights to call his own. It was the ground-plan and first outline only of a picture, to be filled up during succeeding geologic times, and exquisitely finished before man was placed upon the earth.

What effect must all this mass of vegetation have produced on the surrounding air and water ? Plants, we know, are chiefly formed of carbon, taken into their substance from the air and water, under the form of carbonic acid. They have the power of secreting the carbon from it, and they set free the oxygen for the use of animals. So that an atmosphere in a confined spot is actually purer—more oxygen, less carbonic acid—after a plant has grown in it than before. True, they give out carbonic acid at night, but not so much as they take in. All the plant (except water) is so much gained from this carbonic acid. Hence, the air is purified by plants.

Now coal being of vegetable origin, it is calculated that for every pound of coal, all this carbon, and at least two pounds of *water* have disappeared from the atmosphere. And if we consider the millions upon millions of tons, fixed in solid black masses in the crust of the earth, we must see that we are living in an atmosphere far purer, and more fit for the respiration of the higher animals, than it could have been without the aid of coal.

It may have been, as the sagacious De la Beche observed, that this enormous supply of carbonic acid was due to the ejections from many volcanic mouths, which we know breathed forth their fiery exhalations in coal times. It is also true, as Sir C. Lyell has said, that these gases so readily mix with the atmosphere, that little appreciable difference would be made by any quantity of volcanic action. But look at the subject in any light we may, there was the carbonic acid in the air, and there it now is, for our benefit, in the earth.

This rank vegetable produce, then, of quick growth and soft tissue —constantly wet, fermenting as soon as covered up—its heat kept in by a blanket of wet sand or clay, with pressure for ages, gives us all the conditions necessary for the production of lignite, brown coal, jet, and pit-coal; and when volcanic heat had driven away its gaseous parts, and left the carbon pure—even anthracite.

As this month's communication has extended to an unreasonable length, I will not now enter into the question of the different qualities of coal, or its uses, but defer what little I have to say on those subjects till next month.

SOME REMARKS ON MR. DARWIN'S THEORY.

By Frederick Wollaston Hutton, F.G.S.

(Continued from page 136).

But there are other causes that have tended to modify animals; such as habit, use or disuse of any particular organ, food, climate, &c., and these together with the fact that a variation which appears in the parent, at any period of its existence, tends to re-appear in the offspring at the same period, will enable us to account for the metamorphoses of insects, the differences of colour in the young and the adult, the horns of sheep and cattle, &c. If to these we add that of "sexual selection,"* we can see why sexes differ in organs and pro-

* Sexual Selection may be defined as the preference shown by an individual of one sex for an individual of the other from superior beauty of colour, shape, voice, &c.

A LECTURE ON "COAL."

By J. W. Salter, F.G.S.

(*Continued from page* 183.)

I shall now give a few out of many specimens of coal, to show its composition, and so look at it in a practical point of view. For ordinary purposes, there is no doubt the "best" is the best; but whether that best is Welsh, or Newcastle, or Scottish, I do not pretend to say; for the various kinds of coal are suited for different purposes, and what may be refuse in one direction may be of the greatest use in another.

In experiments undertaken with a view to determine what coals were best suited for our steam-navy, Sir Henry de la Beche and his associates tried nearly all the kinds known in Britain, and compared them too with those artificial fuels which are made up from coal-refuse, and are extremely valuable in their way.

I can only give a few examples, and shall refer my young readers —they are older now than when the lecture began, and will not mind a little dry study—to the book itself, if they require more information.*

They tried these coals to see how much they held of carbon, which supplies the heat; of hydrogen, which gives the flame; of oxygen, which is worse than useless in the coal, though essential in the air that is to support the combustion; and, lastly, the quantity of ashes left after the coal was consumed. Because it is clear that the coal which will give most heat, and make least smoke, and leave the least quantity of ash, provided it be not troublesome to manage, must be the best coal to burn.

Now, our steam-navy coal requires all these good qualities. It must have the strongest heating power for the smallest quantity, and the less smoke it makes the better; for that is not only all wasted carbon, but it betrays the position of the ship, when we would fain keep our enemy in the dark as to our movements. Moreover, it should be a coal that does not break or fly to pieces very easily; for the rolling motion of a ship in a gale is very trying to the materials in her hold. Nor is a coal that burns too quickly, and makes the bars white hot, quite the right thing for men to stand in front of, for a stoker with such a grievance might make sad havoc with the engine. All has to be considered; and I believe the government has rejected Welsh anthracite (so good for furnaces), and taken, in the main, Welsh caking coal. Out of three hundred thousand tons

* Memoirs of the Geological Survey, vol. 2, part 2.

used by them in 1860, nearly one hundred and ninety thousand were Welsh coals.

The various qualities stand as follows; beginning with those which have the greatest heating power. The column standing before the name shows how many pounds of water can be converted into steam by the use of a pound of the coal. The column C stands for the carbon; H for hydrogen, which is greatest in the bituminous coals, and by its blaze adds so much to the cheerfulness of the fire-side. Those coals that have most of it are caking coals, which is an additional attraction. Who does not like to poke the fire? But when stern work is to be done, and every ounce of coal is so much added on to the price of iron—then the coal which has most carbon is in request. O, oxygen, is simply a nuisance; for being combined with (H) hydrogen, it forms so much water—a thing to be got rid of before any heat can be got out of the coal.

The best patent fuels have none of it, and Welsh coal has less than Newcastle, and this than Scotch, as the table will show. My own opinion is, that the further you go north, the more it takes to warm you.

Lbs. of Water.	Best Coals.	C.	H.	O.	Ash.
9¾	Welsh Anthracite	91½	3½	2¼	1½
10½	Welsh, Ebbw Vale	89½	5	1⅓	1½
9, 4-5ths	Irish Anthracite	80	2⅓	—	10
7⅓	Newcastle	81½	6	4⅓	3
7	Scotch Coal	74½	5	15½	4⅓
	Patent Fuels.				
10⅓	Warlich's	90	5½	—	3
9	Bell's	87¾	5	—	5
—	Wylam's	80	5½	6½	5
	Inferior Coals.				
8, 4-5ths	Welsh, Rock-vein	75	5	5	11
8½	Forest of Dean	73½	5½	6½	10
8½	Borneo Coal (Tertiary)	64½	4¾	20¾	7½

We see by this table that a large quantity of oxygen and hydrogen relatively to the carbon is a sign of inferiority; and, of course, a great amount of earthy matter, or ash, is so too. I will add, for comparison, some substances which are not coal yet.

	C.	H.	O.
Peat (from many analyses)	60	6	33
Lignite (fossil wood and peat)	58	6	27
Bogwood	57	6	37
Willow wood	51¾	6	41
Oak	50½	6	42
Birch	50½	6	42
Beech	50	6	43

The result is in round numbers: not quite exact.

But then again, no kinds are useless. A coal that has most hydrogen is best for making gas; and the coke will do for the furnace. Parlour-coals should be more caking than those you allow for the kitchen, if such a division could be made. And coal that is so bad that no Englishman would like to burn it, may be exported!

And now we must leave the coal, with one extract from a work that is rather bulky, but full of information. Ronald's and Richardson's "Chemical Technology," vol. 1, treats of fuel and its applications, and from this work what little I have to say of the products of coal will chiefly be taken.* From it we learn that in 1855 the fuel used was divided as follows:—

Household coal	19,000,000 tons
Iron works	13,000,000
Steam, gas, &c.	9,000,000
Export	400,000
	45,000,000
Add for Scotland	7,500,000
„ Ireland	220,000
Total	52,720,000

Our present consumption, as above said (p. 60), is about seventy million tons, and for the future it will probably be greater; and this, remember, is all from the older or true coal-measures. The continent of Europe is supplied, in many places, with coal of a later date.

We must look at some of the products of coal.

It seems hardly necessary to allude to gas, for, like the common blessings of light, and air, and health, we are only sensible what a boon it is when we lose it. It would take a chapter by itself. Gas is now made so carefully, and purified so completely from the deleterious things that once poisoned us, that I believe I am safe in saying that the bisulphuret of carbon is the only impurity they do not remove. Even this, I learn, Mr. Bowditch has lately succeeded in doing.

We are told that a country rector in Yorkshire, Dr. Clayton, of Crofton, first discovered coal-gas; and his letter to the Hon. Robert Boyle attracted attention from the Royal Society—when, do my readers think?—in 1739, fifty or sixty years after! So much for the spirit of discovery at that date. The first person who really used gas for practical purposes, and whose credit ought not to be forgotten, was a Mr. Murdock, an engineer employed by Bolton and Watt in putting up steam-engines at Redruth. He lit up his own house, and afterwards the Soho Works at Birmingham; and even

* I did not know that this celebrated work contained a chapter on the question "What is coal?" till lately, or I should have referred to it at first. The case which gave rise to the discussion was that of "Gillespie *v.* Russell." I need hardly say that my own conviction is, that, in a commercial sense, whatever is a bed of fossil *fuel* is a bed of *coal*. I believe fully that in Dumfriesshire and the county of Down there are beds of fuel made of fossil *Graptolites—sea-animals*. They are very thin beds, but they are true anthracite coal for all that.

made portable gas to light him home from the mines at night. About 1809, the improvement had found its way to London, and one side of Pall Mall was illuminated by gas; and the French, ever on the alert for improvements, lighted parts of Paris with it a few years after. In 1852, four thousand millions of cubic feet were burnt in London alone! and the quantity of coal to supply this was four hundred and eight thousand tons—ten thousand cubic feet or thereabouts to a ton. Boghead Cannel, I learn from Mr. Binney, produces thirteen thousand to fourteen thousand feet per ton.

A table of the products obtained during the distillation of coal is given in the useful work we have referred to (p. 567 in vol. 2); so that may be consulted for details. Besides the coal-tar from the coke, a number of gases are given off, of which the following are to be found in the gasometer:—

Carburetted hydrogen—the principal gas we burn:
Olefiant gas, and some other hydro-carbons:
Carbonic oxide: Hydrogen:
And a very little nitrogen, ammonia, and bisulphuret of carbon—the last a substance they do not as yet remove, though, as above said, they might if they would.

The olefiant gas it is which gives the *bright* light to gas, for carburetted hydrogen without it would produce a very dull flame.

The carbonic acid and sulphuretted hydrogen are separated from the gas by passing it through lime-water. And then there is the combination of stinks (useful in their way no doubt) which make up the "ammoniacal liquor." I can never read the name of this fluid without a shudder. I have fortunately nothing to do with it, and only have time to advert to a few of the products gained by the re-distillation of the coal-tar.

An eminent Scotch professor, at the end of one of his instructive courses, was asked by his students what subjects he would recommend them to work at. His reply was characteristic—"Pitch into the residuary phenomena." This is precisely what our chemists have been doing of late years, and that abomination coal-tar has been made to yield us up such precious things, that "we are tempted," say the authors of the book above quoted, "to anticipate the time when within our own borders"—*i. e.*, I suppose, our black borders—"we shall have all the materials for warming, lighting, and cleansing, which our age demands."

Tar and coal-naptha are the products gained by distilling this coal-tar; and when a crude pitch is removed from the tar,an oil remains of great service in lubricating machinery, and the constituents of which, on further distillation, prove to be the same in kind as those in the naptha, although fewer in number. From both, by processes too tedious to go into here, they obtain the celebrated Paraffin (or napthaline, as it should be called), creasote, aniline (from which Mauve and Magenta are made), Benzole, and Toluole, and a number of other -ines and -oles which would not much edify those who are not chemists.

They are either hydro-carbons or carbo-hydrogens, as the case may be. And then there are acid fats, Rosolic, brunolic, carbolic, &c., which are likely to test the skill and research of our chemists for generations to come.

We can glance at one or two only of the more important of these substances.

Paraffine, or napthaline, which, as above said, exists in the coal-naptha, is, however, more profitably obtained by distillation of the celebrated Torbane Hill, or Boghead coal, and some of the Cannel coals, at a dull red heat; though even at this heat only a portion of the oil can be retained, the rest going off in the form of coal-gas. An analysis of an average specimen of the coal is as follows, side by side with an analysis of the pure paraffin itself:—

Boghead Coal.			*Pure Paraffin.*		
Carbon.........	60 to 65	per cent.	Carbon	$84\frac{1}{2}$	per cent.
Hydrogen ...	$7\frac{1}{2}$ to 9	,,	Hydrogen.........	$14\frac{3}{4}$	,,
Earthy matter	20 to 25	,,	Loss or oxygen...	$\frac{3}{4}$	,,
	100	parts		100	parts

And by this distillation, paraffin oil, naptha, and pure paraffin are obtained. The oil, as before said, is used largely for machinery, the naptha for light; so that a railway train may be driven by the coke, lubricated by the oil, and lighted by the naptha obtained from the same cwt. of coal.

From the oil a crystalline substance, which is true paraffin, is obtained by cooling, and when purified by vitriol, soda, and warm water, yields at last the beautiful candles with which most people are now familiar. We can get oil and spermaceti at last without hunting out and destroying the lord of the polar seas.

Such oils and candles are made from other bituminous shales in our own country. Those of Caithness are chiefly bituminous remains of Old Red Sandstone fish! So Miller and Murchison tell us. And his majesty the King of Ava makes most of his pocket-money by sending us the "Rangoon tar" for this purpose.

The only uses that I know of for creasote are curing ham and toothache; for the fluid used for "creasoting" timber is not creasote, but pitch-oil. We have done now with these acrid and tarry elements, and must say a word on the scented ethers which are found in coal.

For, strange to say, in this dark compound of ill savour, lie imprisoned fairy scents which rival the breath of flowers. Their full history may be found in Ure's New Dictionary of Chemistry, or the original papers by Prof. Hoffmann, in the Philosophical Journal. Prof. Hoffmann himself has been a large discoverer in this, as in all other branches of organic chemistry; and I have heard an anecdote of these researches worth recording here. A lady whom he had admitted to his laboratory while these essences were being manufactured, was so charmed with the odour of hyacinth, that she forgot all about the lecture he was giving her, and sent him a basket next day, crammed with flowers from the greenhouse, that he might have more material at command. He is equally great in coal-colours, but of that anon.

Perhaps the most valuable product of coal-naptha is benzole, or benzile (C^{12} H^{16}). The more volatile portion of the naptha has been shown by Mansfeld* to consist chiefly of this substance, a pale yellow sweetish oil, as inflammable as gunpowder. By distilling naptha in a peculiar way, and at a moderate temperature, first *alliole*, then *benzole*, then *toluole*, pass over successively, while the less volatile *camphole* is left in the water. The first named being the most volatile, and the toluole least so, you may get pretty pure benzole by taking what comes midway. By adding strong nitric acid a nitro-benzole is formed, and this was the first-discovered of all these pleasant odours. It is like that of bitter almonds, and is used in fragrant soaps, &c.: and it is not absent from the cook's repertory.

Toluole has the same properties, and from one or other of these substances (for they play a good deal into each others hands, I am told) a varied set of essences—fruits and flowers—jonquil,hyacinth, tuberose, jasmine, are derived. The famed "millefleurs" is a product of gas refuse. How many gallons of it have been washed into the Thames!

To Hoffmann belongs much of the credit of the original discovery of coal-colours obtainable from *Aniline*. It was he who showed that the best of all tests for the presence of this substance was the chloride of lime, with which it produced the Magenta dye. Of course, intelligent chemists had their eyes open: and Mr. W. Perkins, by a series of independent researches, rendered it a commercial product, and France soon gave it a name—Mauve, Magenta, Solferino. Why should bloody victories be commemorated on our peaceful triumphs of science? We do not grudge our neighbours, however, their undoubted scientific fame; and will give them our best coal for the production of "French blue" from carbolic acid. It is now coming greatly into fashion.

By treating Benzole with acetate of iron *aniline* is produced. But it is made in many ways; and has received many names—*Phenylamine*, *Cyanol*, *Benzidam*, &c.

The oil of coal-tar is shaken up with hydrochloric acid, and the clear liquor evaporated till it begins to decompose and emit acrid fumes. It is then filtered: potash or milk of lime is added to separate the acid, and the oils, chiefly aniline ($C.^{12}$ H^7 N), and leucol (C^{18} H^8 N) remain. This mixture is distilled, and the aniline is found to pass over at about three hundred and sixty degrees, Fahr. It has to be repeatedly distilled to get it pure, and it is best to treat it again with acid, separate this by potash as before, and then again distil.

* Poor Mansfeld, who worked so hard at these ethers, and who discovered *camphole*, literally fell a martyr to his zeal, and died in the odour of sweet flowers; for one of his retorts blew up—and deprived him of life.

The chloride of lime was employed by Hoffmann to test the portions as they passed over; the aniline giving a fine violet colour, while the leucol did not.

The aniline must be crystallized with sulphuric acid to obtain the colour; and the process is thus given in Ure's Dictionary, from Mr. Perkins' account, in brief.

"Dissolve equivalent portions of sulph. aniline and bichrom. of potash in water; mix, and let stand for several hours. Filter, and wash and dry the black precipitate. Digest this in coal-tar naptha to extract a brown resinous substance; and finally digest with alcohol to dissolve out the colouring matter, which is left behind on distilling the spirit, as a coppery friable mass."

To use it, add a strong solution in alcohol to a boiling solution of oxalic acid, and apply when cold to the fabric to be dyed.

But even this is not the last of the coal-miracles. Teetotal advocates may keep watch over every grain of barley; but, alas! we can get alcohol from boghead coal. I never tasted it, nor wish to taste it; but I understand it is yet more sleepy stuff than that from the upper regions. *Requiescat in pace.*

"There is no end," says Mr. Binney, "to the combinations, solid, liquid, and gaseous, which belong to the chemistry of coal. Who shall say these bodies do not change, the one into the other, under various circumstances?" What may we not learn from their investigation regarding the laws—nay, perhaps, even the constitution of matter? And all that is true of coal and its products may be said—leaving a wide margin—for peat and other fossil fuels. They have the same constituent parts, and are among the best of our earthly treasures, although we have sadly wasted them before we knew their value.*

Light, heat, motion, fragrance, and colour—all from coal! What more could the sun himself do for us? Is the heat from below the same with that from above? Robert Stephenson used to say so, and when he saw one of his own locomotives tearing away at the rate of forty miles an hour, would call out, half in fun and half in earnest, "There goes the bottled sunshine."

An acquaintance of mine, who knows coal mines well, gives me the same idea in heroic verse:—

"'Tis the old sun's heat
That now cooks our meat;
'Tis is his bottled up beam
That gets up our steam."

Stephenson was right. It is the light and heat of former days expended in converting carbonic acid and water into coal that is here stored up for man. He can, by again converting coal into carbonic

* Even anthracite was regarded in America, fifty years ago, as incombustible refuse, and thrown away. In 1316, or a little later, it was made a capital offence to burn coal: one man, in Edward 1st's reign, was actually hung for it

acid and water, evolve again that heat and light, and use it in a thousand ways beneficial to his race; nay, essential to his very civilized existence.

> "My heart is awed within me, when I think
> Of the great miracle that still goes on
> In silence round me,—the perpetual work
> Of thy creation—finished, yet renewed
> For ever." BRYANT.

I have said little of iron, though it always accompanies, and is the the very handmaid of coal. For more precious, intrinsically, are these black dirty jewels to England, than her silver mines ever were to Spain. "Give me," said Dr. Percy, in his opening lecture to the working men, "the iron, and the coal, and the brawny arm of an Englishman, and I'll soon have the gold."

In even a short essay like this there have been not a few mistakes due to me, and the printers have to answer for a few more. In p. 10, I said the Whitehaven coal-field—a mere strip—supplied all Lancashire, omitting altogether the Manchester coal-field! I have omitted another point of some importance, viz., the claim which Professor King, of Galway, urges* to have first announced for England, the fact that *Stigmaria* was the root of Sigillaria. I have looked over Prof. King's statements, and am bound to say that he argues the case very ably, and that he certainly thought it was the the root as early as 1842, and gave anatomical reasons for so thinking, as Prof. Brongniart had done in the "Archives de la Museum d'Histoire Naturelle" three years before. Prof. King quotes him for these, so that he does not claim originality on this point.

But the fact will still remain that Mr. Binney, who had been looking out in England for many years to find specimens to establish his opinion, showed to many friends the trees with roots attached, in the Clay Cross cutting, so far back as 1839, the same year that Brongniart predicted it; and also read a paper on the subject at the British Association in 1843. An able prediction is scarcely less fortunate than an actual discovery; and in this case they were simultaneous, or nearly so.

Again, Mr. Binney, to whom, more than to any living Englishman, we are indebted for what we know of our coal-measures, points out to me that I have committed the usual error, in restoring the Sigillaria tree, by making the roots start horizontally from the base of the stem. They do not so. The four great taproots, if they can be so-called, shoot obliquely down for some distance, like the instep of a foot, before they send off the horizontal bifurcating roots. The cast of the

* See his Monograph of the Permian System in England, p. 9, footnote; also the Edinburgh New Philosophical Journal, 1843.

hollow space left beneath these gave rise to the original figure of the dome-shape of *Stigmaria*, and the idea of its being a floating plant, an idea which has figured in a hundred essays on coal. It is an excellent proof how much our logic may go astray with the premises wrong.

Lastly, as a conclusive proof of the marine nature of coal, the presence of very salt sea-water in it, containing iodine and bromine, might have been, and should have been, adduced.

In p. 13, the printers or I have called paper coal "dysoile", instead of *dysodile*.

In p. 183, I am made to say that plants give out less carbonic acid at night than they take in (by day). The words in brackets should not be left out.

But if I attempted to fill up all my own omissions I should fill this number. The greatest fault of all is to have talked in p. 13 of finishing in the next number or so, and then extend over half the year.

A subject of such vital national importance ; a traffic which employs directly half a million of our countrymen ; and whose yearly value, as raw or manufactured material, represents such enormous capital, cannot be a subject of indifference to any man.

The question whether we can afford to go on digging away at the present rate, or even a greater one, and exporting to other nations as well as keeping up our own steam, has been already answered by my friend, Mr. Hull, in his excellent little book, "The Coal-Fields of Great Britain."* His results are summed up in the last page, and may be briefly given.

"1. There is coal, at various depths, over much larger areas than our maps give, down to depths of nine thousand or ten thousand feet, of which we are never likely to reach more than four thousand feet, from increase of temperature.

"2. There is a supply of coal within the smaller limit enough to afford sixty million tons a year for ten centuries."

When our coal-fields are being exhausted, then the grand untouched deposits of America will come into play. Let us get out all we can ; distribute it as widely as the arts of peace require ; use it as carefully as such a blessing should be used, and do all the good with it we may.

* 1861 : Stamford, Charing Cross. A new edition is in the press.