AN

INVESTIGATION

INTO THE

STRUCTURE OF THE TORBANEHILL MINERAL,

AND OF

VARIOUS KINDS OF COAL.

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X.—*An Investigation into the Structure of the Torbanehill Mineral, and of various kinds of Coal.* By JOHN HUGHES BENNETT, M.D., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh. (With Two Plates.)

(Read 6th February 1854.)

The investigation of which I am now about to give an account, was undertaken with the view of determining whether the structure of the Torbanehill mineral was similar to or unlike that of coal. I was aware that the subject would be brought before a court of law, and that many scientific persons of great eminence had already spent much time in the inquiry. With the understanding, therefore, that my evidence, should it be required, was to be limited to the structure of coal and of the mineral in question, I gave directions to Mr BRYSON, the optician, of this city, to make thin sections of attested specimens of various coals and of the mineral, conceiving that a careful examination of them would easily determine the point. It was soon apparent, however, that a far more extended series of researches was necessary than I at first anticipated; but as it was also evident, from the marked structural differences which were observed in the sections, that the investigation would not be destitute of positive results, I determined on pursuing it to a conclusion.

The plan adopted was, in the first instance, to make myself familiar with the structure of the ordinary household coals used in this city, of which those called the Zetland and the Dalkeith or Buccleuch coals may be considered as the types. I then examined the structure of the Wallsend, Newcastle, and various other kinds of household coal, in every case observing, with magnifying powers of various diameters, thin sections made horizontally and longitudinally with the line of stratification. I next examined similarly made thin sections of the Torbanehill mineral, and was struck with the remarkable dissimilarity which existed between them. I now had numerous sections prepared of various cannel coals, and having previously determined the appearances presented by true coal and by the mineral, I was readily enabled to distinguish the various shades of differences between them. I saw that although the cannel coals, and especially one of them, the Brown Methil, approached in structural character to that of the Torbanehill mineral, it could still be distinguished from it by a practised eye; and that although gradations existed between these different substances, there was at least one element which served readily to characterize all the different kinds of coal I had hitherto examined, and which was not present in the mineral. I

now went over the sections of coal in the rich collection of Mr ALEXANDER BRYSON of this city, and subsequently carefully examined the numerous sections made by Dr ADAMS of Glasgow. Before the trial of GILLESPIE *versus* RUSSEL came on, Dr ADAMS, Mr QUEKETT, and myself, spent nearly an entire day together, examining each other's specimens, and carefully re-investigating the whole subject. It was then that the character of the ashes in the various substances we had examined was pointed out to me by Dr ADAMS, who, in my opinion, is entitled to the greatest credit for the laborious, skilful, and successful efforts he has made in determining the structure of numerous coals, and pointing out the differences they exhibited, when compared with the Torbanehill mineral. At this meeting, also, we compared the structure of coal with various kinds of recent woods, we incinerated the mineral and certain coals, and carefully examined the ashes; and there was established, as the result of this conjoined investigation, as well as from the independent researches made by Dr ADAMS in Glasgow, by Mr QUEKETT in London, and by myself in Edinburgh, the most perfect accord with regard to all the facts which had been elicited during the inquiry.

At the commencement of the present session, I brought the subject under the notice of the Physiological Society of this city, who appointed a committee, composed of four gentlemen in addition to myself, all of whom had long been accustomed to the use of the microscope, and were familiar with vegetable and animal structures. Three of these gentlemen, viz., Dr COBBOLD, and Messrs BARLOW and KIRK, made farther inquiries and researches, which served to elicit additional facts, and to demonstrate, in the language of their report, that "the Torbanehill mineral is widely different from every kind of coal." Lastly, with a view of meeting certain theoretical objections which have been advanced, I have carefully examined the structure of various kinds of peat, as well as the stems of recent ferns and several fossil plants, which have only served to establish the entire absence of connection between these substances and the Torbanehill mineral.

In now endeavouring to place in a condensed form the results of this extended investigation before the Society, I propose, in the first place, to describe the facts, as they may be easily demonstrated in the field of the microscope: Secondly, to deduce from these facts the structural element which distinguishes every kind of coal from the Torbanehill mineral, and explain the cause of the differences which are recorded in the proceedings of the recent trial: Lastly, to offer a few speculations as to the nature of this mineral, as distinguished from various kinds of household and cannel coals.

I. When we examine a piece of undoubted coal, such as of the Zetland or Buccleuch coals, it presents to the naked eye a fibrous structure, and has a black shining streak. It has been found difficult to make thin sections of it, as in the grinding process it readily crumbles down. But when a tolerably thin slice, made

in the direction of the fibres, is with great pains obtained, and examined with a magnifying power of 200 diameters linear, it is then also seen to possess a fibrous structure. (Plate I., fig. 3.) These fibres may be observed to be composed of a reddish-brown coloured substance, in the centre of which is sometimes a dark streak. Oval and elongated transparent masses of a light yellow or reddish-brown colour may also be seen running parallel with the fibres, and here and there are colourless spaces, which strongly reflect light, and which are evidently filled with a crystalline mineral substance.

On examining a section horizontal to the former one, parallel with the plane of stratification, a bistre-brown or blackish opaque mass is seen, containing a number of rings of a transparent yellowish or reddish colour, with an opaque centre. These rings are from the 1000th to the 1500th of an inch in diameter, and resemble the transverse sections of tubes running at right angles to the fibres of the coal. (Plate I., figs. 1 and 2.) There may also be observed larger masses of a reddish-brown transparent material, varying in size from the $\frac{1}{6}$th to the $\frac{1}{200}$th of an inch in diameter. There are also visible, circles or rings of a rich golden yellow matter, much larger, and varying in size from the 50th to the 6th of an inch, which have been described by some as seeds or spore cases. (Plate I., fig. 1. Plate II., figs. 13 and 14.)

Similar appearances may be observed in the Wallsend, Newcastle, and all the other household coals I have examined, although in some of them, especially Newcastle coal, this structure is more obscured than in the Scotch coal, by dense black opaque matter. Here and there, however, in the Newcastle as well as in the Hamilton and some other coals, it may be found to present a highly fibrous fracture, minute chips of which exhibit at their edges distinctly dotted or porous ducts. (Plate II., figs. 5, 6, 7, 8, and 9.)

On examining the Torbanehill mineral with the naked eye, it is destitute of a fibrous structure, and presents a homogeneous appearance in whatever way it is fractured or cut. It is tough and hard to break, when compared with coal, has a dull brown streak, and is readily ground down into thin slices of any degree of tenuity. Some specimens are of a dark, and others of a light brown colour. The section of a dark specimen seen under a magnifying power of 200 diameters, presents, first, a number of yellowish and reddish-brown transparent masses, of a rounded form with an irregular outline, varying in size, from the $\frac{1}{4000}$th to the $\frac{1}{200}$th of an inch in diameter (Plate I., fig. 10). These are surrounded by a dark opaque substance, in which they appear to be imbedded, and in which no trace of structure can be detected. These light and dark substances vary in relative amount in different specimens of the mineral, and according to the thickness of the section. In some specimens, the rounded transparent masses are more widely separated, by the opaque substance, but in others, they are often so close, that a very thin section presents a homogeneous appearance of yellowish or reddish-

yellow matter, resembling bees-wax, with only a few irregular spots of the black matter. In some sections, especially of the light-brown specimens, the rounded masses, as they are ground thinner, may be seen, as it were, to melt into one another (Plate I., fig. 11). In such sections, no difference whatever can be made out, whether they be made in a longitudinal or in a horizontal direction. But in certain sections, the yellow masses assume an elongated shape, so as to resemble the appearance represented, Plate I., fig. 9.

In some thin sections these rounded transparent bodies can be separated from one another, and be distinctly seen to possess a radiated crystalline appearance, strongly reminding one of the crystals of carbonate of lime which occur in urine. (Plate II., fig. 1.) At certain angles, also, a few of them refract light, and become strongly tinted with the orange ray when polarized,—a circumstance perhaps dependent on the admixture of mineral matter. When a section of the mineral, presenting both the substances described is held over the flame of a lamp, the yellow matter evaporates in the form of thick smoke, leaving the black matter unaffected, with large holes or loculi in it. It must be clear from this experiment that the yellow matter is some bituminous or resinous substance, easily decomposed by the heat of a lamp, and that the black matter is an earthy material, which resists the same amount of heat. We can have no doubt, therefore, that an easily volatilized and highly inflammable matter has concreted in the form of rounded masses, and constitutes the light-coloured portion of the mineral formerly described. Whether this be chemically the same as, or only allied to bitumen, resin, or amber, I leave to be determined by chemists. But we may at least correctly denominate it a *Bituminoid* substance, that is, one which closely resembles, even should it turn out not to be identical with, bitumen. The matter in which this is imbedded seems for the most part to be composed of clay, or earthy matter which leaves a white ash, altogether destitute of structural traces, and is equally amorphous in whatever direction the section of the mineral is examined.

Some portion of the Torbanehill mineral, however, has a tendency to split up into thin laminæ, and presents smooth or irregular depressions, dependent on the presence of Stigmaria or other fossil plants, which, in these places, come in contact with, or are imbedded in, the substance of the mineral. Thin sections of such portions exhibit masses of a rich brown colour, composed of scalariform ducts in great numbers, and occasionally the woody fibres and rings of coal. These latter are most common where the mineral forms a junction with coal, and where the one is more or less mingled, or alternates with the other. In these places the great difference in structure between them is easily recognized both by the naked eye, and by microscopic demonstration. By the naked eye, the black shining layers of coal are easily distinguished from the brown dull appearance of the mineral, and wherever such coal exists, the streak is dark and lustrous; wherever

the Torbanehill mineral is pure, and unmixed with vegetable matter, it exhibits the dull brown streak. In such places, the mineral is characterized, under the microscope, by its yellow masses and black basis; the coal, by its rich brown fibrous structure. (Plate I., fig. 12, and Plate II., fig. 2.) Occasionally sections at the point of junction, prove that the scalariform tissue, like the substance of coal, is very friable and easily broken down. This fact which was pointed out to me by Mr KIRK, induced him to think that the amorphous basis might be composed of such tissue disintegrated, a supposition negatived by the absence of all trace of structure through the mineral generally.

From what has been said it must be evident, that there is a wide distinction between all kinds of household coal and the Torbanehill mineral, and the correct discrimination between the fibrous, woody texture of the one, and the granular bituminoid, and earthy substance of the latter, will enable us to understand the more confused texture presented in certain cannel coals, which it has been contended are identical in structure with the mineral.

I have examined a large number of cannel coals, and in every case have been enabled to recognise the fibrous structure of the longitudinal section, and the appearance of rings in the transverse sections, as they are seen in household coal. They contain, however, a greater or less number of the bituminiod masses, identical with those which constitute the principal substance of the Torbanehill mineral.* (Plate I., figs. 4 to 9.)

The Capeldrae and brown Methil coals are especially rich in these bituminoid bodies, and in consequence have been regarded as identical in structure with the mineral. In some sections of the latter coal, they are almost as numerous as those in the dark specimens of the Torbanehill mineral; but a careful examination will show that it also possesses the same organic structure as coal, and may be at once distinguished by its reddish fibres, when cut in one direction, and by the distinct rings, though few in number, observed on a transverse section. (Plate I., figs, 8 and 9.)

I consider that this proof of structure in the brown Methil coal, is decisive of the question as to the distinction between coal and the Torbanehill mineral. Every one allows, that of all the cannel coals, the brown Methil is the one which most closely resembles it. It has also been reported that no difference can be detected between them by the aid of magnifying glasses. To this I may reply, that I have always been able to distinguish them at once; that I have never been deceived in doing so, although the attempt has often been made; nor do I believe

* In reference to this point, I have carefully examined transverse and longitudinal sections of the following household and cannel coals, namely,—Buccleuch, or Dalkeith; Zetland; Newcastle; Wallsend; Jordan Hill; Knightswood; Arniston; Sheepmount; Drumfillan; Cowdenhill; Barton Hill; Eastfield, Glasgow; Stonilaw, Glasgow; Gartnavel, Glasgow; Claycross; Lesmahagow; Wemyss; Lochgelly; Capeldrae; Wigan; Civility Pit; Huddersfield; Bredisholm; Black Methil; and Brown Methil.

that any histologist who has made himself acquainted with the structure of coal on the one hand, and of the Torbanehill mineral on the other, could easily confound the two together.

There are two other modes of examination which also indicate the broad distinction in structure between coal and the mineral. These are by reducing them to powder and to an ash.

The powder of household coal contains numerous short black fibres, separated or aggregated together, mingled with mineral particles and fragments of cells. That of the Torbanehill mineral is composed of transparent yellowish masses, evidently the same as those seen in section, but more broken up, and without any trace of an envelope, mingled with fragments and the debris of the dark amorphous mineral matter. This mode of examination, though distinctive between the household coals and the mineral, is not so much so, when the brown Methil coal is chosen as the subject of comparison.

An examination of the ash, however, is still more characteristic. In the brown or blackish ashes of coals will be found, 1*st*, A greater or less number of mineral spicula, evidently the skeletons of the woody fibre; 2*d*, Siliceous masses of various irregular forms, obtained from the interstices of the organic substance; 3*d*, Black fibres, separated or in masses, evidently the woody fibre carbonized; 4*th*, Flat carbonaceous plates, presenting round apertures corresponding in size to the woody cells which passed through them, and exhibiting at their margins sections of larger circles, which doubtless bounded the large resin cells in the recent wood. (Plate II., fig. 3). None of these appearances are visible in the ash of the Torbanehill mineral, when care is taken to exclude such portions of it as are free from the stigmaria or other plants imbedded in it. Indeed I myself have never seen such appearances in the ash, even when no such precaution has been taken. Dr GEORGE WILSON gave me a considerable quantity of it, which everywhere exhibited nothing but an amorphous material, such as might result from the incineration of clay or other earthy non-organic substance. (Plate II., fig. 4). In all the cannel coals, traces of these forms, though not so numerous or abundant, can be seen. Mr QUEKETT has even applied this test to Welsh anthracite, in which substance no rings or fibrous structure can be made out in sections, yet where he says, the ash gives unmistakable evidence of the presence of woody tissue.*

II. Such, then, are the facts which an investigation into the structure of coals the one hand, and of the Torbanehill mineral on the other, has elicited. If the account I have given of them be correct, it must be evident that the differences

* Quarterly Journal of Microscopical Science, No. VI., p. 43. This number of the Journal for January 1854, was not published until February, after the present paper was written. I was enabled however, by the kindness of Mr HIGHLEY, the publisher, to peruse a proof of Mr QUEKETT's valuable paper, before my own was read to the Society, and to interpolate the above passage.

they present are marked and distinctive; that the one is essentially a woody structure, whilst the other is not. Every kind of coal, including the Brown Methil, may be at once distinguished from the Torbanehill mineral, by the rings contained in a well-made transverse section. I further contend that such an appearance constitutes, in the majority of cases, a practical and evident test, distinctive of genuine coal, and that by means of it all kinds of known coal, whether household or cannel, can at once be distinguished from the Torbanehill mineral.*

Now if this be the case, it may well be asked how it happened that, at the late celebrated trial,† so many persons, all of whom represented themselves as being skilful observers with the microscope, should have been made to give diametrically opposite evidence, not only as to matters of opinion, but as to what appeared to be matters of fact? In endeavouring to place the remarkable histological controversy which has originated out of the trial of GILLESPIE *versus* RUSSEL on its correct basis, it must be remembered that unquestionable organic structure is only present in the Torbanehill mineral at certain places. No one, for instance, can doubt that the scalariform ducts seen by all parties are of vegetable origin; but it is nowhere pretended that these were everywhere present in the mineral. It is of great importance, therefore, not to confound the organic plants imbedded in a substance, with the substance itself. The occurrence of Stigmaria or other vegetable remains in coal, or in the Torbanehill mineral, no more constitute those substances coal, than they convert sandstone and limestone into coal, in both which rocks they are also found. Nor do I imagine it can be generally maintained that because animal substances, such as teeth, jaw-bones, or the skeletons of fishes and lizards, are occasionally found imbedded in stone, that therefore they form an essential and necessary part of the stone itself. At the trial, great amount of confusion resulted from not keeping this distinction clearly in view.

Thus when Mr QUEKETT‡ stated that all that which may be supposed like vegetable structure in the Torbanehill mineral disappears when the structure is thin, he was asked by the Dean of Faculty, "When you speak of that which appears as vegetable structure, you mean those isolated fossil plants?" to which Mr QUEKETT unfortunately answered, "Yes;" for what he really meant was, not

* Considering that hitherto no distinct definition of coal has yet been made, and that the efforts of mineralogists and chemists have only shewn that those differences they have detected are of degree rather than of kind, the structural distinction here pointed out must be of great importance.

† "A full report of the trial before the Lord Justice-General and a special Jury of the Issues in the action at the instance of Mr and Mrs GILLESPIE, of Torbanehill, against Messrs RUSSEL and SON, coal-masters, Blackbraes, for infringement of lease of coal, ironstone, &c. Reported by Mr ALEXANDER WATSON LYELL, short-hand reporter. Edinburgh: Bell and Bradfute. London: Longman and Co.; and W. Maxwell, 1853." 4to, pp. 246.

This report is acknowledged by all parties to be very accurate, and it may therefore be regarded as a trustworthy record of the scientific opinions held by numerous individuals, concerning the mineralogical properties, chemical composition, and minute structure of the Torbanehill mineral and of various kinds of coal.

‡ Mr LYELL's Report, page 67.

the isolated imbedded plants, but the structure of the mineral itself. In consequence, the counsel for the pursuer and for the defender truly played at cross-purposes throughout the whole of the structural evidence; for, notwithstanding the clearness of Dr BALFOUR's statement, he was asked, after saying that the mineral consists of a plant, whether he had seen fossil plants in stone? to which he answered, Yes. But then being asked whether he considered that an example of such an appearance, he very correctly, according to his views, answered, No.

From the published report of the trial, however, by Mr LYELL, it is evident that the eminent gentlemen who contended that the Torbanehill mineral was a vegetable substance abounding in cells, did not adopt this idea because various plants were imbedded in it, but because they believed the clear rounded masses I have described were themselves vegetable cells. Unfortunately, the possibility of this theory being adopted had not been anticipated, nor was it perceived by the counsel for the pursuer. In consequence, the witnesses on the one side were made to declare that the Torbanehill mineral was not vegetable, and on the other that it was, without the true reason of this discrepancy ever having been made to appear.

Dr BALFOUR stated in court, that he believed the yellow part of the Torbanehill mineral to consist of vegetable cells; that it was not the mere impression of a foreign fossil, but the actual structure of the mineral at that place.* In the same manner Dr REDFERN, when asked,† "What do you think these yellow spots indicate?" replied, "They indicate the existence of vegetable cells." The reasons he gave for so considering them were, "That they can be perfectly isolated—they project upon the edges of all sections of the mineral—they are rounded—they are as uniform in size as the cells of other vegetable structures—the general appearance of the section is that of a piece of vegetable cellular tissue—the yellow spots do not act upon polarized light, or act upon it very feebly."

Dr GREVILLE, also, speaking of the same bodies, said,‡ that "he had no more doubt of their being vegetable cells than he had of his own existence;" that "in one specimen it was so unequivocally marked, and so regular, that it might be compared to that of a recent plant;" and that "no person accustomed to botanical sections would hesitate in believing it to be cellular tissue."

From these quotations it must be evident that both parties saw the same things, but that while on one side it was contended that they were not vegetable cells, but bituminoid masses imbedded in clay, on the other it was strongly asseverated, in the language I have quoted, that *because* they were vegetable cells, therefore the Torbanehill mineral was a fossil plant. But in consequence of the reason of this difference in opinion not having been distinctly brought out in examination, the greatest confusion seemed to prevail in the minds of judge, counsel, and jury; and it was thought that the witnesses for the defender being skilful botanists, were enabled to see what the witnesses for the pursuers did not see.

* Mr LYELL's Report, pp. 168–9. † Ibid., p. 170. ‡ Ibid., pp. 171–2.

This result, as well as the confusion occasioned by the examination of the witnesses, is evident from the observations made by the learned Judge to the jury, from which I shall take the liberty of quoting:—

"One general remark may be made on the microscopic testimony, and it is, that there are those who see a thing, and also those who do not see it.—those who do see it, cannot see it unless it is there, and those who cannot see it do not see it at all. But very skilful persons looking for a thing and not seeing it, creates a strong presumption that it is not there. But when other persons do find it, it goes far to displace the notion that it is not there. But there is another observation on the microscopic evidence that occurred to me. I do not know whether I am under any misapprehension, but I think that three, certainly two, of those examined by the defenders are botanists also; and I do not think that any of those examined for the pursuer, three of them from London, represented themselves as botanists. Now the defenders' witnesses are accustomed to look for plants, and can understand them when they see them. The gentlemen on the other side, again, looking for woody fibre or tissue, are not, as I understand, conversant or skilful in fossil plants."*

Now, so far from the botanists seeing what the histologists did not see, it is nowhere made to appear in their evidence that they ever observed those rings on a transverse section, which I have endeavoured to show are distinctive of true coal. On the contrary, they contended that coal and the Torbanehill mineral were similar in structure, the elements of the one existing in the other, both containing vegetable cells; that the numerous yellow clear masses observed in the latter were in point of fact such cells, and constituted the proof of vegetable organization.

I think it of great importance to rescue the mode of investigation by means of the microscope from all reproach in this case, and to point out that the discrepancy which existed is not one of fact, but one of inference. I hope then it will be evident that the true scientific controversy is altogether connected with the question of whether these yellow masses, which both parties saw, described, and figured, are or are not vegetable cells.

Now the view taken up by myself from the first, and which was also taken up by Dr ADAMS and Mr QUEKETT, independently of each other, was that they are not cells, but masses of a concrete bituminoid or resinoid substance, imbedded in earthy matter. We could nowhere discover in them any trace of cell wall or contents. Their mode of fracture was more crystalline in its character than anything else; they occurred confusedly together, and nowhere presented that definite arrangement to one another, or to ducts and woody tissue, which exists in plants. Numbers of them present no envelope or definite boundary, but are scat-

* Mr LYELL's Report, pp. 238–9.

tered through a substance often more than two feet deep, extending for acres, and it may be for miles. If these yellow masses be cells, what is their origin? They cannot come from the woody tissue of the neighbouring coal, for, as we have endeavoured to show, such coal is destitute of them. The rings in coal are much smaller in diameter, are of regular size, and present the character of a tube cut transversely. Such rings could never be confounded with the yellow masses of the mineral. But supposing these latter to be cells, could such multitudes of them be derived from the gigantic ferns of the coal formation, or such as are imbedded in the mineral? I think not; because the amount of scalariform and woody tissue is too disproportioned to the number of the cells to favour such an idea. Besides, what kind of force or power could have been in operation that would have separated and collected the delicate cells, and left the ducts and other tissues of the plants by themselves, and out of sight, throughout such enormous masses. I have carefully examined the cells in large ferns, and observed the singular markings of cellular tissue, woody fibre, and scalariform ducts, many of them present, visible even to the naked eye,—than which nothing can be more unlike the Torbanehill mineral. The cells themselves are also larger, of more uniform size, and contain numerous starch granules; whilst the true resin cells are exceedingly large and distinct, strongly analogous, indeed, to what I have described as existing in the woody texture of coal, but wholly dissimilar to any thing observable in the Torbanehill mineral. Such a view, indeed, would, it seems to me, lead to the extraordinary conclusion that this mineral is composed of a vegetable tissue, more cellular than any plant ever yet met with, recent or fossil, and so rich in cells as to be wholly dissimilar to what we can even imagine to have existed, taking its size and bulk into consideration. Such masses of cells could not have been formed or nourished without ducts passing through them in various definite directions, to convey a nutritive fluid; and yet we find such ducts only to be accidental, and only distinctly connected with plants imbedded here and there in the general mass.

Whilst, then, the notion of these yellow masses being vegetable cells seems to me opposed to every known or conceivable fact yet ascertained to exist in vegetable histology, or from such as are demonstrable in the Torbanehill mineral, the theory of their being bituminoid masses imbedded in clay, appears to be in perfect harmony with all of them, and especially answers the reasons given by Dr REDFERN.

With a view of determining whether the Torbanehill mineral could by any possibility be produced by a process similar to that of the formation of peat, which was described at the last meeting of the Society by Dr FLEMING,* I have examined various specimens of peat, and have confirmed his description. They consist of mosses, especially of the Sphagnum, the spiral cells of which plant are peculiar, and easily recognized, associated with broken-down woody tissue, root-stalks, and bundles

* Proceedings of the Royal Society of Edinburgh. Session 1853–4, p. 216.

of simple ducts, more or less carbonized and condensed together. The deeper the peat is taken from the bog, the more condensed, broken up, and altered these textures are; still, however, sufficiently retaining their characters to be readily distinguishable. The peat of Scotland between this and Glasgow, and that of the north of Ireland, of which I have examined numerous specimens, taken from mountain bog, as well as the flow bog, are identical in structure. One specimen of peat, however, given to me by Dr TRAILL, which he obtained in Lancashire, and which answers in description to what is called Pitch Peat, is blacker in colour, the carbonizing process is more complete, and the vegetable tissues less distinct. But here and there, in a thin section of this peat, there exist rounded masses of the same bituminoid character as are found in the cannel coals and in the Torbanehill mineral. This fact confirms the theory formerly advanced, that these bodies are not cells, but a concrete bituminoid substance, probably derived from the beds of coal in Lancashire, in the immediate neighbourhood of the peat.

We may therefore conclude that every kind of coal has a distinctly woody basis, which is easily demonstrated by its longitudinal and transverse sections; that the cannel coals have, in addition to this woody structure, a greater or less number of the bituminoid masses imbedded in it; and that the Torbanehill mineral has no such woody texture, but is essentially composed of the bituminoid masses imbedded in clay.

III. In the third place, the theory which I am disposed to put forward as most in harmony with the various facts and arguments previously stated, is as follows:—1*st*, That the various organic appearances found in the sections and ashes of coal, are explicable by the supposition that coal is wood chemically altered, and for the most part coniferous wood, or wood allied to it in structure, because, from a careful comparison of recent fir wood with the various kinds of coal, I find the structural appearances of the cellular tissue, resin cells, and ducts, to be very similar. Further, no fir wood growing in this country contains spiral ducts; and it is remarkable that no traces of such ducts are to be found in any of the coals I have examined. Further, the assumption that coal is formed from fir or allied woods, not only explains its structure, but accounts for the large amount of bitumen, resin, or inflammable matter it contains, resin being a well-known abundant product of the coniferous tribe of plants.*

2*d*, The Torbanehill mineral, although it presents essentially no traces of ve-

* In the above passage, I have carefully avoided any expression which would suggest the notion that in my opinion the wood from which coal is formed, is *exclusively* coniferous wood. I believe, that with regard to the varieties and even genera of the plants of the coal-formation, there is still much to be discovered. But so far as my examinations have gone, the appearances observed warrant the general inference stated in the text, one which has also been arrived at by Mr QUEKETT. (*Mic. Journal*, No. vi. p. 42.) The important fact to be kept in remembrance is, that coal is fossil or transformed wood, whilst the Torbanehill mineral, and all the shales which I have examined, are not.

getable structure, is rich in the bituminoid substance;—a circumstance, I think, explained by the fact that it is found in the neighbourhood of coal, so that the bituminoid or resinoid matter formed in the partially woody structure of the latter has flowed out, mixed itself with, and solidified in the essentially earthy substance of the former. It is easy to conceive how enormous pressure, conjoined with chemical change and heat, may have effected this, and how sometimes such fluid bituminoid matter may have run into neighbouring beds of peat, of clay, or even of sandstone. Facts, indeed, are not wanting to show that occasionally large collections of such substance, almost pure, may be formed, unmixed with either peat or clay, of which the remarkable specimen I now exhibit to the Society, taken from the Binnie Quarry, and for which I am indebted to Dr CHRISTISON, is an example. Fragments of this substance, under the microscope, closely resemble the yellow masses which exist in the Torbanehill mineral.

In conclusion, I would remark that the controversy on this subject is only an example of a far more extensive one which is now everywhere taking place throughout the natural sciences, in reference to the influence which more improved methods of research in chemistry and histology should exercise on our thoughts and nomenclature. Those who, with myself, recognise that differences in structure indicate differences in function, and that these should be studied as the foundation for a correct classification, will recognise in the question, what is coal? an analogue to the questions, what is wood or coral?—what is bone or tooth?—what is a fibrous or a cancerous tumour? The progress of science, and especially of micro-chemistry, has already answered some of these questions, and will ultimately determine others; and in doing so, will overthrow the more vague and incorrect views and terms which previously prevailed. At the trial, indeed, it was very plausibly argued, that, in a bargain between man and man, scientific terms were of no value, and that a whale among whalers was still a fish.* But in this Society, as no naturalist, conversant with the structure and functions of a whale, would for a moment suppose it to be a fish, because it inhabits the water and resembles one; so I contend no histologist, acquainted with the structure and properties of the Torbanehill mineral, ought to maintain that it is coal, because it is dug out of the earth and burns in the fire.

* Mr LYELL's Report, p. 231.

Description of the Plates.

PLATE I., Fig. 1. Transverse section of Buccleuch or Dalkeith coal, magnified 80 diameters linear. It displays imbedded in the bistre-brown mass, 1*st*, The rings described in the text; 2*dly*, The reddish masses supposed to be resin cells; and, 3*dly*, The large circles considered to be sections of spore cases.

Fig. 2. Another portion of the same section, magnified 200 diameters linear, showing more particularly the appearance of the rings held to be characteristic of coal.

Fig. 3. Longitudinal section of the same coal. 200 diameters linear.

Fig. 4. Transverse section of the Wemyss cannel coal, showing, in addition to the rings, several bituminoid masses. 200 diameters linear.

Fig. 5. Longitudinal section of the Wemyss cannel coal. 200 diameters linear.

Fig. 6. Transverse section of the Lesmahagow cannel coal, showing a less number of the rings, but a greater number of the bituminoid masses. 200 diameters linear.

Fig. 7. Longitudinal section of the Lesmahagow cannel coal. 200 diameters linear.

Fig. 8. Transverse section of the Brown Methil coal, showing very few of the rings, but a greatly increased number of the bituminoid masses. 200 diameters linear.

Fig. 9. Longitudinal section of the Brown Methil coal. 200 diameters linear.

Fig. 10. Transverse section of the darker coloured Torbanehill mineral, showing the bituminoid masses imbedded in clay. No rings are anywhere visible. 200 diameters linear.

Fig. 11. Transverse section of the lighter coloured Torbanehill mineral, showing the deep orange-coloured masses, and the melting together of the bituminoid masses. 200 diameters linear.

In these sections it will be observed, that common coal abounds in the rings, and possesses no bituminoid bodies. The cannel coals have rings and bituminoid bodies, whilst the Torbanehill mineral is principally composed of the bituminoid masses without any rings at all. It will be further seen, that in different cannel coals these various elements vary greatly in amount.

Fig. 12. Transverse section of the Torbanehill mineral, at the upper portion of the seam, where veins of coal run through it. 200 diameters linear.

PLATE II. Fig. 1. Bituminoid masses imbedded in the clay of the Torbanehill mineral, at the edge of a section, magnified 750 diameters linear, to show their radiated texture, and mode of fracture.

Fig. 2. Section of the lighter coloured Torbanehill mineral, in which a plant is imbedded, showing the scalariform vessels. 200 diameters linear.

Fig. 3. Ashes of the Zetland coal, showing mineral masses and spicula, black fibres and plates, perforated with round openings. 200 diameters linear.

Fig. 4. Ashes of the Torbanehill mineral, showing their amorphous structure. 200 diameters linear.

Fig. 5. Punctated woody tissue, apparently coniferous, from the needle-coal of Töplitz in Bohemia; from a specimen sent by Professor HARKNESS (magnified 190 diameters).

Figs. 6 and 7. Dotted or Pitted vascular tissue (Bothrenchyma) from Arniston coal (magnified 190 diameters).

Figs. 8 and 9. Pitted vascular tissue, from Fordel coal (magnified 190 diameters). This kind of tissue is common in the carbonaceous matter, which is often found between the laminæ of coal, and which soils the fingers.

Fig. 10. Pitted vessel from coal with the dots elongated transversely, and giving a scalariform appearance (magnified 190 diameters).

Fig. 11. Scalariform vessels from coal, resembling those of ferns (magnified 190 diameters).

Fig. 12. Seed-like bodies or sporangia, found in vast abundance in Fordel splint coal, natural size.

Fig. 13. The same sporangia magnified about 8 diameters, imbedded in a mass of Fordel coal; some lying on the surface, others projecting from the broken edges of the coal. They seem to occur frequently in coal from different localities, both in Scotland and in England. Mr BINNEY has seen them in Wigan coal. Similar sporangia occur in enormous quantity in specimens of a brown inflammable deposit sent by Sir W. DENISON from Van Diemen's Land.

Fig. 14. Section of Fordel coal, showing the sporangia as viewed by transmitted light, and magnified 20 diameters. The orange-yellow lines indicate the walls of the sporangia cut across in a microscopic section.

Fig. 15. Sporangium magnified 20 diameters.

Fig. 16. Valves of sporangium separated, containing a quantity of black carbonaceous matter in its interior (magnified 24 diameters).

Fig. 17. Sporangium cut transversely, showing the internal cavity (magnified 24 diameters).

Fig. 18. Sporangium cut obliquely, showing the cavity and the dark-coloured contents (magnified 24 diameters).

Fig. 1.

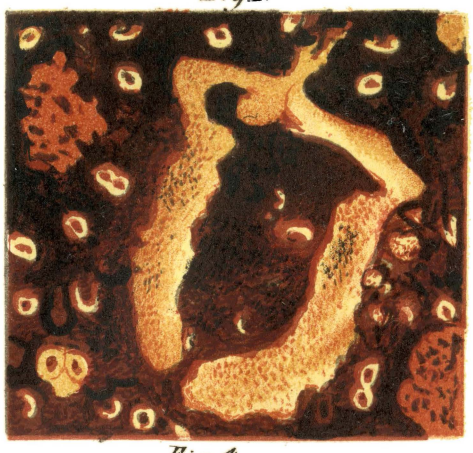
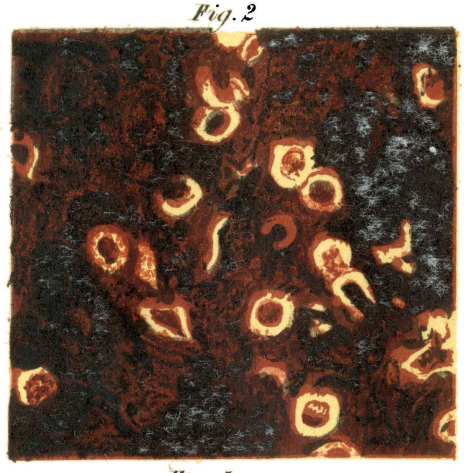


Fig. 2



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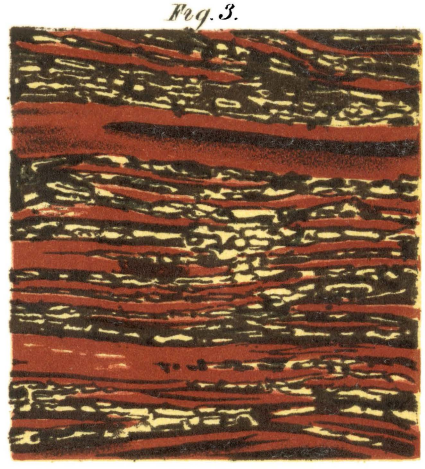


Fig 4

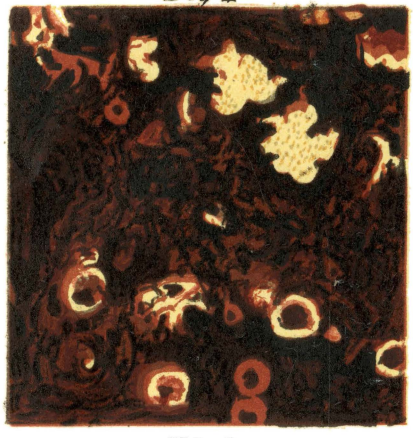
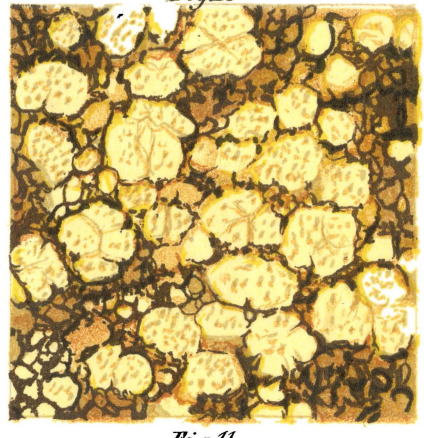


Fig. 5.

Fig. 10



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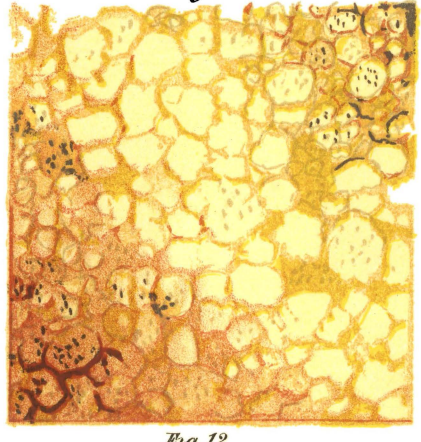

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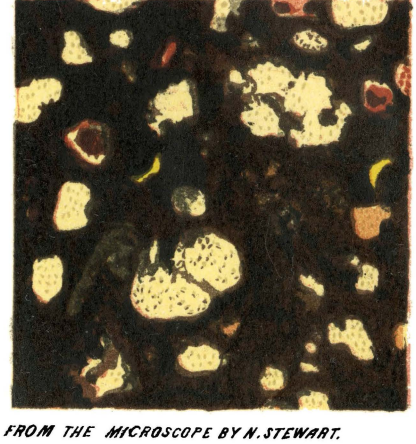

Fig. 9.

Fig. 12

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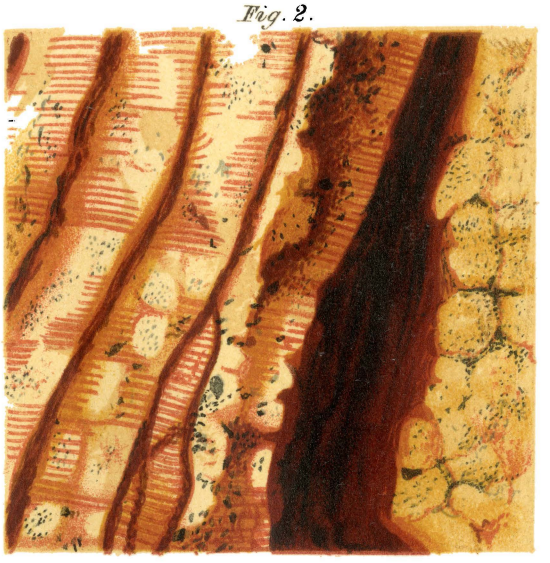
Fig. 1.

Fig. 2.



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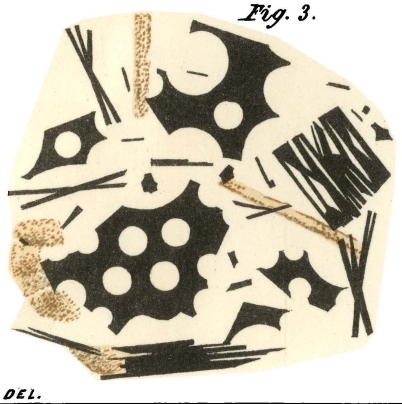

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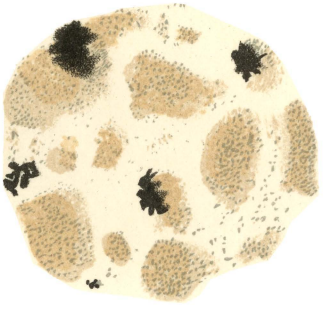
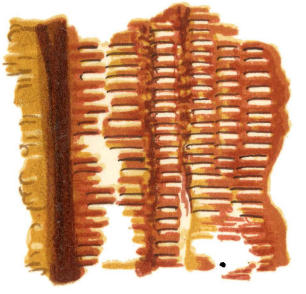


Fig. 11



J. H. BENNET DEL.

Fig. 6.

Fig. 7.

Fig. 13.

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Fig. 9.

Fig. 12.

Fig. 15.

Fig. 14.

Fig. 17

Fig. 18.

Fig. 16.

R. K. GREVILLE DEL.

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