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ORDINARY MEETING.—October 23rd, 1928.

Chairman—Mr. K. J. Cook.

"THE ORIGIN, FORMATION AND CHARACTERISTICS OF COAL"

BY

Mr. W. L. Whittle, M.I. Mining Engineers.

Imagine a vast continent to the North-East and North of the present position occupied by the British Isles, with a system of rivers draining its area and the rivers flowing into and forming one large river, which eventually, by means of a deltaic formation, empties its volume of water and suspended material into a sea where the British Isles, Belgium, Germany and part of France now exist. These were the preliminaries to the origin of the coal seams.

Present day examples of this process of continent destruction and rebuilding are many. Some in this island, which will assist to make the action understood, are the coast erosion of the Lincolnshire area, several miles of which have disappeared under the North Sea since the time of the Romans.

The Holderness (Yorkshire) coast line has been calculated to disappear at a rate averaging from 5ft. to 7ft. per annum along a coast line of 17 miles.

The River Ribble in Lancashire is depositing sediment in the sea off Southport at such a rate that in a few years Southport will not be a seaside resort, as the sea will be quite a considerable distance away.

The silting up of the Wash is familiar to everyone.

For examples approaching the coal measures river and delta in magnitude consider the deltas of the Nile and the Ganges. The delta in each case occupies a very large area and is extremely fertile; the delta of the Nile allows three crops a year to be gathered.

The coal measures delta was also very fertile and owing no doubt to the internal temperature of the earth being higher in carboniferous times, an extremely luxuriant growth of water loving plants and swamp vegetation flourished.

This vegetation which grew in the form of trees, creepers, ferns and mosses died and others grew, until beds of peat began to form underwater. It has been estimated that 20 feet in thickness of peat would produce 1 foot in thickness of coal, so that one can imagine the vast periods of growth and decay necessary to produce a moderately thick seam of coal. The carboniferous period occurred at a relatively early stage of the solid condition of the earth's globe, when volcanic activity was very great; earthquakes were frequent and the earth's crust was folded, contorted and many faults or slips produced.

The coal measures delta was submerged in one of these great folding or bending movements, and, the whole area being under water, the river began to deposit mud again, covering the vegetation with layer after layer, until the delta was again formed and vegetation flourished once more.

Bending movements again submerged the vegetation and so the creation of another seam was commenced.

This took place several times; to what extent may be judged by the fact that a section of the carboniferous strata in some areas in Yorkshire produces 26 seams of coal.

At times the sea flooded the area and deposited a layer of sand, forming a marine band of sandstone. Several of these marine bands are found in quarries and shaft sinkings.

The evidence proving the origin of coal from swamp vegetation is supplied by the fossil remains of the trees, ferns and mosses, several hundreds of varieties being recorded and practically all the strata is rich in these stone records.

Fresh water shells, marine shells, impressions of ferns, fern trees, fossils of insects and also small aquatic reptiles occur frequently in the shales being worked in the coal mines.

FORMATION.

As the strata subsided the seams naturally became compressed with the weight of the overlying mud, which also being compressed formed shales, binds and sandstones.

The internal temperature of the earth also was communicated to the layers of vegetation and the change from peat to a semi-coal termed lignite took place gradually. As the depth and temperature increased the lignite changed to bituminous and then to anthracite.

Lime in solution in the water saturated strata filtrated into the crevices of the coal and into the coal tissues.

The white substance noticed on pieces of coal is calcite or aukerite and forms the interesting feature termed "cleat."

Mr. P. F. Kendall, Emeritus Professor of Geology in the University of Leeds, obtained information from collieries in practically every coal producing country in the world of the direction of these cleat lines and found they take a general direction in the Northern Hemisphere of N.W.–S.E. and vice versa in the Southern Hemisphere. A counter-cleat runs at right angles to the main cleat and this forms the cubes of shale and coal familiar to miners and quarry-men.

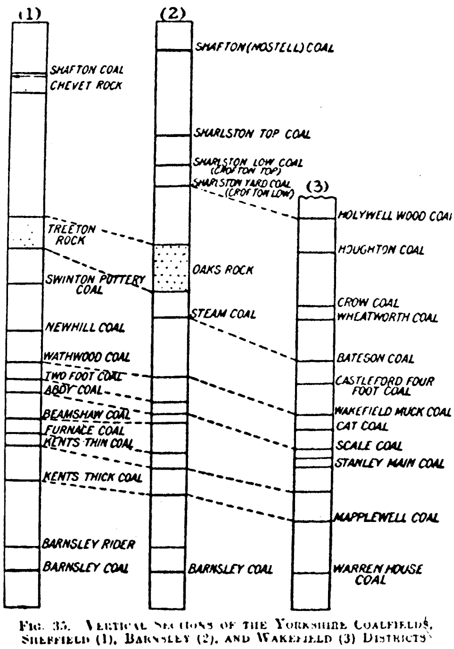

Fig. 35. Vertical Sections of the Yorkshire Coalfields, Sheffield (1), Barnsley (2), and Wakefield (3) Districts
Scale, one inch = 400 feet

FIG. 1.

This cleat is common to the chalk formation and a suggestion has been made that the rotation speed of the earth has something to do with the phenomenon.

In the operation of mining the coal, the direction of the cleat is important and the roadways and working "faces" of the coal are set out according to it; the coal worked across the cleat forming cubes of regular shape is called "End" coal and that worked with the cleat is termed "Bord" coal. The "Bord" coal produces thin slabs which are usually easily broken in transit.

As several other strata of subsequent periods covered the carboniferous, some explanation is necessary of the re-appearance of the coal measures to within working distance from the surface.

The folding and bending movements continuing, denudation by ice, frost, rain and river agents took place and the Pennine Chain or Range elevated the central ridge of England lifting the coal measures above them.

On the Yorkshire side the seams rise towards the West and one by one come out to the surface in the direction of the Pennines.

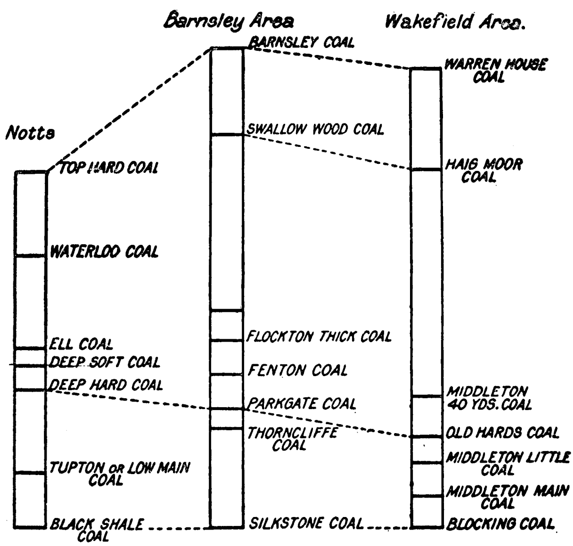

Fig. 33.—Vertical Sections (Silkstone to Top Hard) of the Yorks-Notts Coalfield.
Scale, one inch = 400 feet.

Fig. 2.

On the Lancashire side the opposite applies. Wherever a seam comes to the surface it has been given the name of the locality where it "outcrops," hence the name of the famous "Barnsley Bed" which outcrops at Barnsley, Haigh Moor seam at Haigh, Stanley Main at Stanley Nr. Wakefield, Silkstone at Silkstone. The last seam to outcrop on the Yorkshire side is named "The Halifax Hards" as it outcrops near Halifax. Figs. 1 and 2 are sections showing coal seams and their names according to locality, and Fig. 3 gives a sketch map of the East Midland Coalfield.

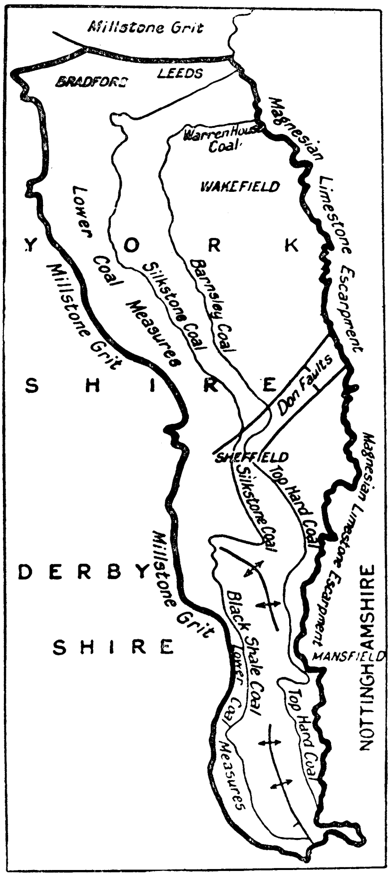

Fig. 3.

Many of the seams receive local names and this makes it very difficult to correlate them, but if a coal earns a reputation on the market other collieries may find they have a similar seam in their section. The famous "Wallsend" house coal was worked at Wallsend Colliery several years ago, but although now worked out, it is surprising the large number of Wallsend seams that have been discovered in every coal-field in England; a coal evidently becoming fashionable in the same manner as other commodities.

On analysing coal its resemblance to vegetable matter is striking. Under the microscope it reveals the original cellular tissue of the plants, etc. The microspores and megaspores, or seeds, seed pods and spores are surprisingly numerous.

Instances can be given of whole seams being composed of nothing but masses of spores. Figs. 4 to 11 give illustrations of this. The chemical change from peat to coal can best be illustrated by a table giving the percentage of carbon in the different stages:—

	% Fixed carbon.
Peat and turf	below 55
Brown lignite	30 to 55
Black lignite	35 to 60
Cannel	35 to 48
Low grade bituminous	48 to 73
High grade bituminous	48 to 73
Semi-bituminous	73 to 83
Semi-anthracite	83 to 93
Anthracite	over 93
Graphite	over 99

ULTIMATE ANALYSIS.

	Carbon.	Hydrogen	Oxygen.	Nitrogen.	Sulphur.	Ash.
Hay	45·23	5·85	39·18	2·13	...	7·61
Peat	54·02	5·21	28·18	2·30	0·56	9·73
Lignite	66·31	5·63	22·86	0·30	2·36	2·27
Caking Coal	78·69	6·00	10·07	2·37	1·51	1·36
Non-caking Coal ...	78·57	5·29	12·88	1·84	0·39	1·03
Cannel	80·07	5·53	8·08	2·12	1·50	2·70
Anthracite	90·39	3·28	2·98	0·83	0·91	1·61

The above table gives an average for the qualities named, but owing to the variations not only in different seams, but also in the seams themselves, a separate analysis is necessary for each.

Owing to the high market price of coal and keen competition in industry, the basis on which coal is purchased and sold has altered considerably in recent years. Collieries are compelled to erect costly washing and screening plants to enable them to compete for contracts for the supply of clean coal. "Washing" alone is a process which has taken years of patient and costly research work to reach a practical and paying solution and much remains to be done to find an efficient method of drying the coal after it has been washed. Dry-cleaning is as yet in its infancy, but spiral separators, cleaning tables and glass table separators are all being tried.

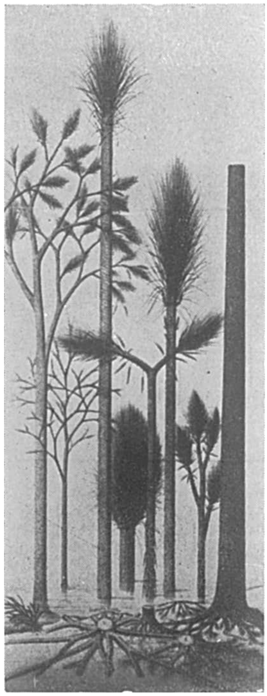

FIG. 4.—Restoration of carboniferous period trees—Sigillaria. and Lepidodendron.

They all naturally have advantages and disadvantages, the greatest difficulty occurring in the varying specific gravity of even a small piece of coal when broken into smaller fragments. All systems of cleaning, wet and dry, depend on the difference in the specific gravity of the coal and the impurities. The impurities include shale or slate, pyrites or brasses, calcite and mixtures of coal and shale.

The usual question received by a colliery to-day is, "What moisture, ash, volatile and carbon content have you in your grades of coal, and what is the calorific value?"

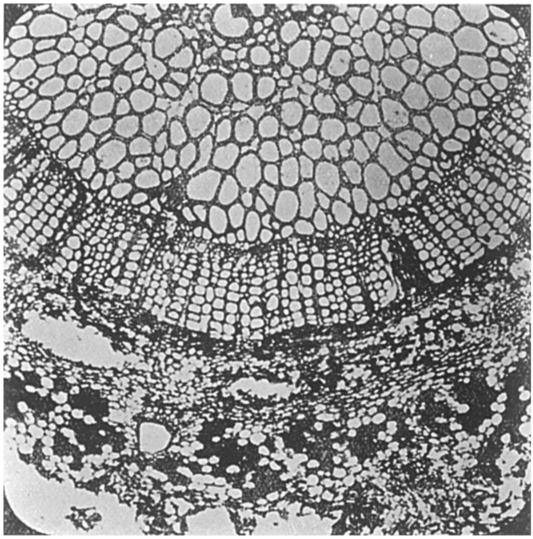

FIG. 5.—Photograph of a branch of the carboniferous tree Lepidodendron.

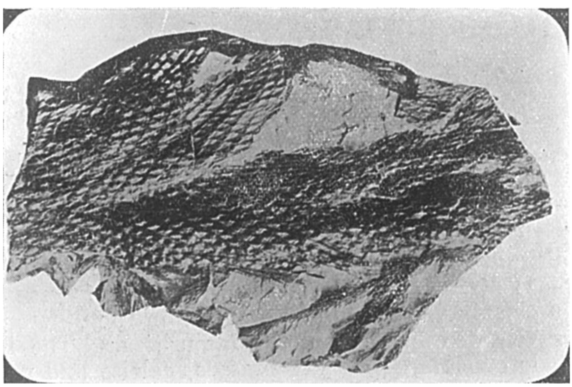

FIG. 6.—Microphotograph of part of stem of Lepidodendron tree.

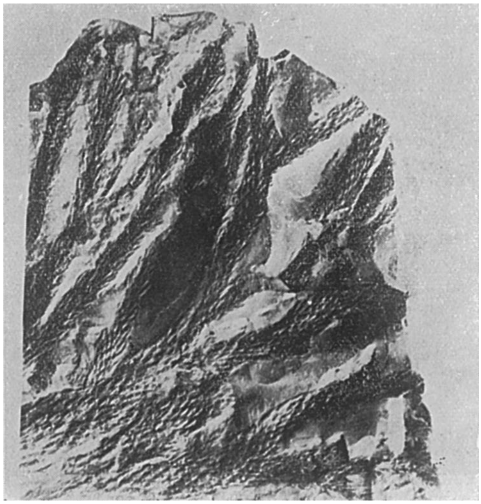

Fig. 7.—Fossil of Lepidodendron Lycopodioides from Barnsley thick coal, Monckton Main Colliery.

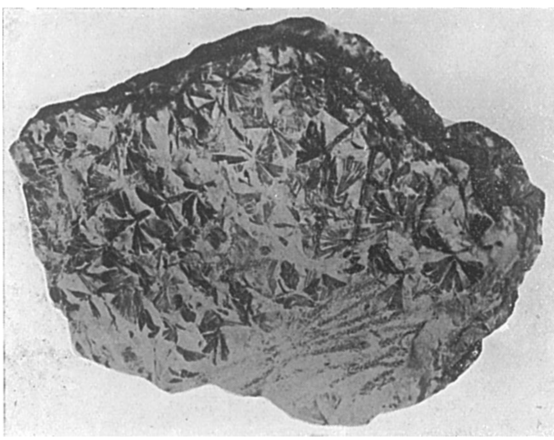

Fig. 8.—Spenophyllum—Barnsley coal, middle coal measures.

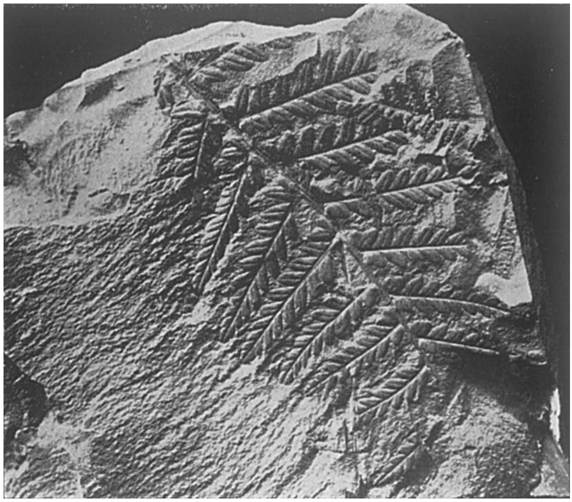

FIG. 9.—Fossil of Calamites (a giant horsetail plant).

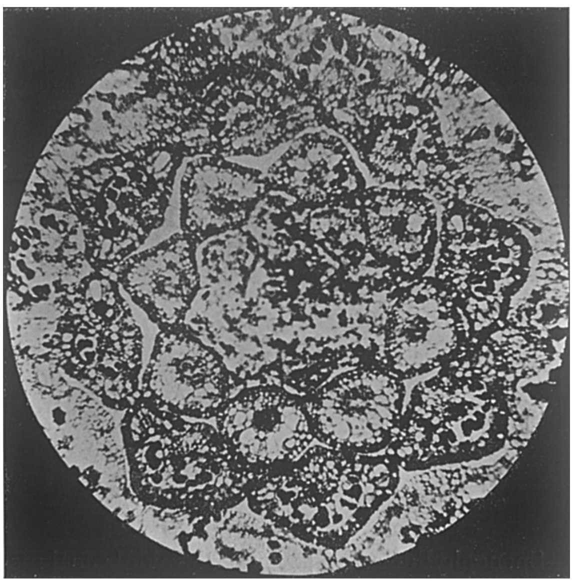

FIG. 10.—Fossil of Mariopteris fern.

Many collieries rely on the analysis made when the seam was first worked, but as the buyer also makes a control analysis the former is useless and an accurate analysis of the ash content, and also the sizes, has to be made to hold any position whatever in the industry.

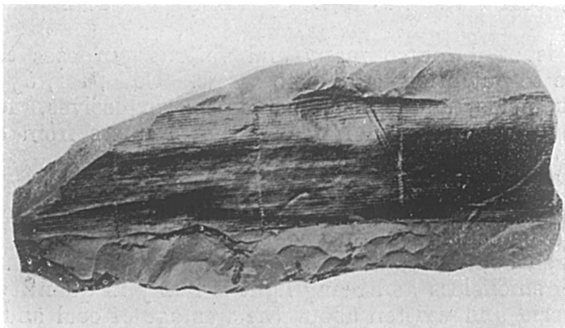

Fig. 11.—Microphotograph of a section of tip of Sphenphyllum.

The characteristics of coal which determine whether it is a gas, house, coking or steam coal have to be studied very closely, as a seam which has a reputation as a good coking variety at one colliery may change completely at one a few miles away.

Each seam needs to be tested in every possible way to prove its suitability. For coking and iron and steel work the sulphur content is of necessity most important. Locomotive coal must not leave an ash which clinkers. House coal must not leave a white ash. These are a few of the points which have to be seriously considered.

Dr. Marie Stopes and Dr. Wheeler have recently studied various properties of coal in connection with mining problems, and they have divided coal into four ingredients:—

Fusain—a black, sooty fibrous material.

Durain—a dull, firm and hard material generally containing numbers of spores.

Clarain—clear and bright, in streaks, containing many plant tissues and structures.

Vitrain—a pure coal occurring as very bright and irregular patches.

They give the following interesting figures as the analysis of the four ingredients:—

PROXIMATE ANALYSIS.

	Vitrain.	Clarain.	Durain.	Fusain.
Moisture %	12.6	10.2	6.5	3.9
Ash %	1.2	1.45	3.6	10.0
Vol. matter on ash free dry coal	38.6	40.8	39.4	22.6

Coal is used for so many and various purposes that it is impossible to but briefly allude to a few. Coke, tar, dyes, medicines, oils, acids, antiseptics, perfumes, explosives, fertilisers, these show the unlimited range of the products from coal.

Low Temperature Carbonisation of Coal is rapidly coming to the front, producing a soft coke named "Coalite" for domestic use and also a percentage of oil and other bye products. "Coalite" gives an ash content of about 5.6% and about 14,000 B.T.U.s, is practically smokeless and being light is bulky in quantity. Much has been said and written about the wastage of coal and particularly in connection with the smoke problem of cities.

For steam raising purposes many patent methods of stoking have been tried to economise in the quantity of coal burnt.

The methods adopted are to regulate the amount of coal and air necessary for complete combustion, and CO_2 recorders and various devices for controlling temperature and draught are legion.

A method which hag been tried recently is to pulverise the coal to a fineness approaching 200 mesh (or practically fine enough to pass through a piece of silk) and feed it to the furnace through a burner similar in design to an oil fuel burner. This method gives on test a very high efficiency, over 80% being common. The difficulties are in pulverising, conveying and slagging in the furnace.

When it is considered that there is sufficient energy in 1lb. of coal to lift one ton one mile in height, or to develop over 300 horse power, the principle behind the use of pulverised coal is apparent.

The Author has burnt small coal, passing 1-16″ mesh, in Lancashire boilers fitted with turbine furnaces obtaining 73% efficiency; and passing the same through the Buell system of firing pulverised coal on boilers in the same range, 83 to 85% efficiency was obtained on test.

As this system is in its experimental stage various methods of fire brick linings and arches are being tried and also the arrangement of the burner fittings to enable the flame to be used to the best advantage and to control the combustion. The coal used in the above tests contains 20% ash and gives about 10,500 B.T.U.s. This method has been and is being used for marine purposes and savings of 20% are claimed.

Much scientific research work is being done in the production of oil from coal and methods of subjecting the coal to pressure under hydrogen are meeting with a great measure of success, one method giving 85lbs. of oil per ton in a recent test.

DISCUSSION.

The Chairman (Mr. K. J. Cook) stated that the discussion would have to be brief in order to allow time for the exhibits to be examined.

He thought that if the outcrop coal was good enough to be worked during the coal disputes, it would also be worth while to work it under normal conditions, but perhaps the quality had something to do with it.

With regard to the white lines mentioned by the Author; in examining some coal he had been struck by the lines in it having the appearance of gold leaf, and enquired if that were a form of calcite but taking a different colour.

The Author had referred to the fact that the various seams had different names in different places. He would like to know if these coals in different places had compositions of a similar nature. It was found that some of the Welsh coals that were claimed to be exactly the same, behaved differently in the furnaces. He would like the Author's opinion whether it was a modification of the suggestion that the same coal, obtained at various places, was called a different name, or whether it was due to the fact that another seam had been struck.

In reply to the question of outcrop coal, the Author said that there was no doubt that it was inferior in quality to the coal obtained in the mine. Running water, etc., got into the cracks and washed clay and shale into them. The outcrop coal could be shovelled up without first having to be blown to pieces, which was a much cheaper method than that which had to be used underground. In order to produce 5,000 tons of coal per week a colliery had to fire 2,500 shots, each shot containing 2lbs. of safety powder, to blow the coal into pieces so that the men could work it easily. A $7\frac{1}{2}$-hour day was in operation; it took about an hour to get to the work, and an hour to get back, so that the miner had only $5\frac{1}{2}$ hours in which actually to get the coal.

The gold leaf effect referred to by the Chairman was iron pyrites, which was one of the biggest bug-bears in mining. Mining engineers blamed pyrites for causing spontaneous combustion. The pyrites was acted upon by the damp, warm atmosphere, heat being generated; this heat attacked the coal and fire was rapidly produced.

With regard to the question about the seams, the Author said that he could take a person to the "Priory" seams of the Nostell Colliery and shew him some coal, and the remark would be made that it was a first-class coal. He could then take him to another part of the same seam, and it would be difficult to convince him that it was the same seam. In fact, the collieries were often accused of mixing the coal.

Mr. C. T. Cuss said how much he had appreciated the Author's paper. He had been greatly impressed by the diminution of the lapididendron from 160 feet to 4 inches. He was interested in the silicon surfaces of these growths in the pre-timber days, as it might not be generally known that there were, in the Thames a few miles from Swindon, some rushes with silicon surfaces which would cut through a pair of oars in a short time. The present method of producing the glaze on the china of the Japanese variety was to burn these rushes to ash and use the silicon for the glaze.

He had been given to understand that the prosperity of this country depended upon the cheap production of coal. If there were, as the Author suggested, over-production, he would like to know why it could not be more extensively employed to lower costs and help in the prosperity of the country, and, indirectly, the railways.

He was a little disappointed to hear that the Author held out no hopes in the direction of pulverised fuel or low temperature carbonisation.

The Author, replying to the question of over-production, said that the collieries were up against the working cost. For instance, some of the mines were 1,000 yards in depth, and if anyone knew of an engineer who could supply a satisfactory winding rope to wind from 1,000 yards in depth to the surface, there was a fortune awaiting him. A rope 3″ in diameter lasted about three months. The Nostell Colliery mine went down 404 yards; the engine started with a load of 12 tons and it had to accelerate and pull up dead within a distance of $\frac{1}{4}$″. This had to be done 60 times an hour. One could imagine the stresses in the engine and rope. Another aspect of the cost was the middle man between the producer and the consumer. There were always a certain number of middle men who had to make a living out of it, and that was a problem that neither the Author nor his listeners could overcome.

The Author said he did not wish to give a pessimistic idea about the future of pulverised fuel. He would say that it was the mining industry's only hope. It might be so successful that eventually the Navy would adopt it. There was already one ship fitted, and the chief engineer claimed 20% saving.

As regards the question of producing oil, there were experiments going on in London which were turning out successful. The Author was sending coal to London for testing, and from one ton of coal, 85 pounds of oil was obtained. At present the best system was doing very well if it could produce 30 pounds per ton. The latest method was to dissolve the coal by compressed hydrogen, but there was the question of getting steel to stand up under the pressure. The steel became embrittled, and finally cracked.

Mr. Cuss enquired if the questions of pulverising the coal in the shafts at a low level, and of making dry coal live so that it could be forced forward in a stream to the surface had been considered.

The Author replied that twelve months ago his chief had made an offer to any maker of pneumatic suction plants to instal one at the Nostell Colliery, but nothing transpired. There was one system in Nottinghamshire on similar lines. Instead of the men having to fill the coal into the troughs, as was the usual practice, there was a pipe which sucked the coal up and filled it into tubs.

Pulverising at site would probably come in time as conditions would compel it. Shafts would be at such a depth that winding would have to be done in two or three stages. It was a question of depth, as to whether it was economical to work at 1,000 yards. All the shallower seams were worked out, and so the thicker ones had to be worked.

Mr. C. T. Roberts said that presumably each strata of coal was older than the one above it, and he would like to know whether the calorific value of the coal varied in the same way as the depth. He also enquired if the delta ceased to function after each seam of coal has been laid down, and then started again at some later period.

The Author, replying to the question of depth and the varying calorific values of the coal, said it must be considered that every time the delta silted up there was a different phase of growth, that is, at any one time there was a particular type of growth which made a particular class of coal in calorific value. In these beds one can get a dull seam composed of nothing but megasphores; there was a different value in each different bed of coal. The dull coal had a greater calorific value than the bright. In fact, if some coal be split up there would be a different calorific value in each layer. In one case there might be an ash of 1.4%, whereas in another there would be an ash of 9.8%. In one, the calorific value was 14,500 B.T.U.s, and in the other it was 11,000 B.T.U.s. In the same seam there were these variations, so that it could readily be seen that the seams themselves varied greatly.

With regard to the question about the delta, Mr. Roberts was quite correct. The delta ceased to function, then the water from the river overflowed, and the land gradually sank. The northern part of Norway was, to-day, gradually rising out of the water; there were raised patches of land around the Fiords at different levels, proving that the land was gradually rising. Sweden, on the other hand, was, in some parts, gradually sinking below the sea. In the northern parts the fishermen had had to put in new stakes because the old ones were too far from the sea, and in the southern parts new ones had had to be put in because the sea was gradually submerging the old ones. That action was still going on to-day.

Mr. A. C. Harvey said that the Author gave the calorific value of coalite as 14,000 B.T.U.s. Since oils and other matter had been taken out, he assumed that a portion of the calorific value had also been taken away, and if that were the case, the original calorific value of the coal must have been very high.

The Author explained that the calorific value of a substance was in the terms of B.T.U.s per pound of that substance, so that one could have 1lb. of coal at 14,000 B.T.U.s per lb., and also coalite, produced from that pound of coal, also at 14,000 B.T.U.s, but the amount of coalite might only be about ½lb.

The coal trade was the best to-day, and it was a question of making oil so that this country could compete with the foreigner who had the monopoly as far as oil fuel was concerned, and if coal could be used to produce oil a new market was opened up. The mining industry wanted people to waste coal; it did not want 85% efficiency from pulverised fuel, it wanted people to burn coal. It was all very well burning gas and electricity to purify the atmosphere, but that was of no use to the miner or the mining industry. A Commission that sat a few years ago said that the coal supplies would only last another 400 years; therefore everyone must economise; they had economised, and in so doing had done harm to the mining industry, and so other means had to be found of using coal. It was hoped that pulverised fuel would be one means of using more coal in ships and trains, and that oil production would be another. It was quite evident that the mining industry had been asleep, and it must wake up and find some other methods of getting rid of the coal.

Mr. Harvey, referring again to the question of the price of coalite, and that he understood that there was a strong committee called the Smoke Abatement Committee, and he gathered that this committee was more or less subsidised by the people introducing coalite.

The Author replied that in Yorkshire particularly this was being put up as a strong card in its favour.

Mr. E. H. Gooderson said that coal was a very homely thing, and he suggested that more of it be burnt, but from a personal point of view he would like to say that if he were supplied with a good house coal he would be very pleased to burn more. He did not know why it was not possible to get good house coal, but it was a fact that the collieries issued coal which was impossible to burn. He would like to ask the Author where it was possible to get good coal for the house, as, to many people, it was a question of very great importance.

The Author said that if the last speaker went to every colliery in Yorkshire he would find that there was not a single colliery that did not produce good house coal. A great number of people got the idea that coal mining was quite a simple operation, and that the coal had only to be shovelled out of the mines straight away into wagons. As a matter of fact it was quite different. The Nostell Colliery had put up new screens this year at a cost of £25,000 to deal with the question of keeping house coal clean, but one always had to take into account the human element. There were men employed to pick out the good from the bad, and one could stand by them telling them what to pick out and what not to pick out, but as soon as one walked away, they did something quite different; there were thousands of tons of first-class coal going out as "seconds" because of their mistakes or carelessness. There was, of course, a good trade in "seconds" as it was cheap. Here was an example. The Author found a man throwing coal from one belt to another. He picked up a piece and shewed the man that although he was putting it with the "seconds" it was a first grade coal, but as soon as the Author's back was turned he was doing the very same thing again. It would have paid the colliery to have paid that man his wages to stay at home as it meant a difference in the price of 10s. a ton.

Mr. L. Day remarked that as the seams varied so very considerably in value according to depth, he would like to know the best method of getting a good average quality under analysis.

The Author said that when he made an analysis with "limit" coal he took a section through the middle, and one from each end, tipped them out on the floor, broke them down small and ground them down as in metal analysis. With "nuts" he did the mixing in the wagon. The middle and the ends of the coal in the truck were well mixed, and a sample was then taken from the wagon. If a sample be taken from the middle of the wagon the worst would be obtained, and if from the ends, the best. It would always be found that the worst would be in the middle of the wagon in the same way that if anything were combed, the large particles would tend to get to the outside, and the fine stuff get in the middle. If a separate analysis were taken for the middle and ends of the wagon, two different values would be obtained.

In conclusion the Author gave a list of some of the products obtained from a hundredweight of coal:—

5.35lbs. of tar.
3.75lbs. of pitch.
$\frac{1}{8}$ oz. of anthracene.
$1\frac{1}{4}$ lbs. of creosote and fuel oils.
7 lbs. of ammoniacal liquors.
1.3 lbs. of ammonium sulphate.
1.4 lbs. of 100% H_2SO_4.
2.0 oz. of toluene.
$\frac{1}{4}$ oz. of phenol.
$1\frac{1}{8}$ oz. of naphtalene.
2.0 oz. of naptha.
7.0 oz. of benzene.
$2\frac{1}{4}$ oz. of sodium ferrocyanide.