EXPERIMENTS ON COAL DUST EXPLOSIONS.[1]

A PRELIMINARY record of experiments made with coal dust, and other work of various kinds, carried out by a committee of colliery owners on behalf of the Mining Association of Great Britain, has lately been published in an elaborate and splendidly illustrated volume.

In the introductory chapter the committee quotes the remarks of John Buddle (1803) regarding "the shower of red-hot sparks of the ignited dust which were driven along by the force of the explosion," and those of Faraday and Lyell (1884): "There is every reason to believe that much coal gas was made from this dust in the very air of the mine, *by the flame of the firedamp which raised and swept it along*, and much of the carbon of this dust remained unburnt from want of air."[2] A general list is then given of those who have taken part in the investigation since 1875 (not 1870 as stated), regardless of chronological order, and reference is made to the opinions expressed by the Royal Commission, 1891–4, and of a committee consisting of the members of the Royal Commission of 1906, which is still in existence, and an advisory board associated with it, to the effect that experiments with coal dust should be made on a larger scale than any hitherto undertaken. The circumstances which induced the Mining Association of Great Britain to undertake to find the necessary funds, which were estimated at 10,000*l*., are also described.

The committee illustrates in cross-section some of the different galleries in which previous coal-dust experiments were made, as well as those now being employed in France and England, and finally sums up the results of the work of its predecessors as follows:—"These galleries or tubes have in no instance been of sufficient size to allow of the conditions prevailing in a mine being reproduced." "Neither were they of sufficient length to obtain the development of explosive force nor of sufficient strength to resist the latter if obtained. The inflammability of coal dust had been demonstrated by Faraday."

Again, in the first paragraph of chapter iii. the committee says:—"As has already been stated in the Introduction, one of the most important objects of this inquiry has been to demonstrate as conclusively as possible the great danger that exists from the presence of coal dust on the roadways of a mine, and by ensuring the absence of gas to definitely establish the fact that it is not essential that firedamp in addition to coal dust should be present for an explosion to be propagated."

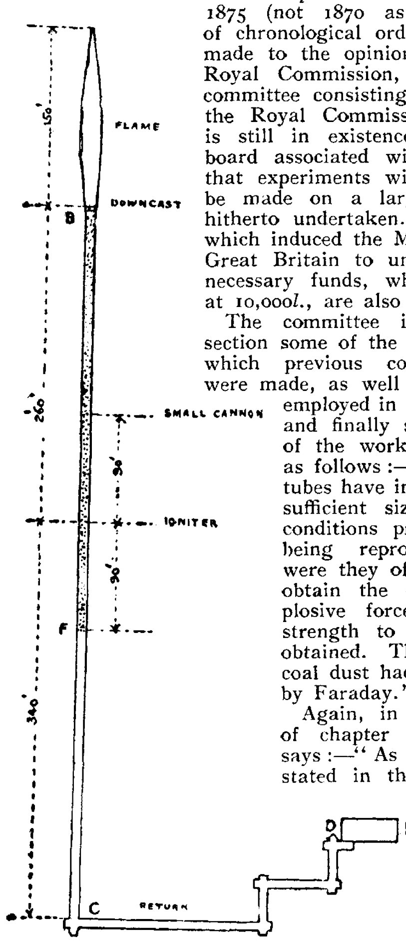

FIG. 1.

These historical references are singularly curt and inexact. Whatever may have been the actual motive that dictated them, they have the appearance of being an attempt to set aside any possible claim to having done really useful work by those who occupied the field in the interval between the time when Faraday showed by an experiment that flame is enlarged when coal dust is allowed to fall upon it and the present day. They appear to simulate ignorance of the fact that the dangers due to the presence of coal dust, both with and without the simultaneous presence of firedamp, was conclusively proved long ago—the explosion at Altofts Colliery in 1886 (Proc. Roy. Soc., vol. xlii. 1887) having been, itself, the culminating proof on a gigantic scale of the second alternative.

Does the British colliery owner, as personified in the committee, hope, by thus assuming the airs and manners of Sir Oracle to conceal his own laches in having hitherto, with few exceptions (of whom the late Mr. Archibald Hood may be taken as the most brilliant example), contributed nothing towards the solution of the coal-dust question, but contented himself with classifying those who were bearing the burden and heat of the day as faddists and theorists?

One can understand the grief and dismay of the French Government engineers who, by their inept criticism of the present writer's experiments and conclusions and of his description of Penygraig explosion (1880) (Proc. Roy. Soc., No. 219, 1882), and by their own abortive experiments with coal dust, lulled themselves and their fellow-countrymen to sleep twenty-eight years ago, on being rudely awakened by the Courrieres explosion, with its holocaust of more than 1100 men.

One can sympathise with the confusion of the United States Government engineers at being caught lagging in the rear of an important movement.

But it is difficult to understand why one's own countrymen should be less generous than were the Prussian Government engineers, who showed Sir W. Thomas Lewis and the present writer a most violent explosion of air and coal dust, "without any admixture of firedamp," in their gallery at Neunkirchen on October 25, 1884, frankly avowed that they drew their inspiration from the present writer's earlier work, volunteered the statement that he was the inventor (*sic*) of the method of proving the explosiveness of coal dust in an experimental gallery, and added that his gallery of 1880–1 (for which the Government Grant Committee of the Royal Society provided the funds) had served as a model for their own.

These blots upon a work that is otherwise admirable in many respects ought to have been avoided at every hazard. There was plenty of room for the colliery owner to come in with his gigantic apparatus to demonstrate the dangers of coal dust to himself, his officials, and the community in general, without having to push others aside in the process.

The demonstrations with the Altofts apparatus are so overpoweringly convincing that, in the opinion of the present writer, the Government ought to make it obligatory on the part of everyone who holds a mine manager's certificate to have seen them. They constitute, as the committee itself properly observes, the most important function of the apparatus, before which all the other questions which it proposes to investigate pale into obscurity.

The second chapter is devoted to a description of the experimental gallery, the method of preparing the dust, and the means of raising and igniting it.

That part of the apparatus (Fig. 1) in which the explosions are effected is a straight tube AB, 7 feet 6 inches in diameter, made up of the outer shells of steam boilers with their ends abutting against, and fixed to, each other, 600 feet long, open at one end, closed at the other, and with a branch CD, 6 feet in diameter, also made up of boiler shells, which extends at right angles from the closed end of the tube AB to an exhausting ventilating fan at E.

The branch CD is bent four times at right angles to itself, and is provided with two relief valves at each bend, one at A and another opposite the junction at C, making ten altogether, which open when an explosion takes place, and thus protect the fan from injury. A segment in the bottom of the explosion gallery, with an arc 5 feet wide, filled with concrete, constitutes a level floor on which a line of rails of 25-inch gauge is laid. The rails rest on sleepers 3 feet apart, embedded in the concrete. Five rows of wooden shelves, 5 inches wide by $\frac{3}{4}$-inch thick, fixed on iron brackets, extend along each side of the gallery from

[1] "Record of the First Series of the British Coal Dust Experiments, conducted by the Committee Appointed by the Mining Association of Great Britain. A Record of the Experiments carried out during 1908 and 1909 at the Altofts Experiments Station." Pp. viii+212. (London: The Colliery Guardian Co., 1910.) Price 10*s*. net.

[2] The italics are the reviewer's.

A, which is called the downcast end, to F, a distance of 350 feet, which is shaded in the sketch.

For seven minutes before, and also while the experiment is being made, the fan draws air into and through the gallery from its open end at the rate of between 50,000 and 60,000 cubic feet per minute.

The dust employed in all the earlier experiments up to the twenty-fourth was obtained from the colliery screens, but in all subsequent experiments (exclusive of some made with dusts from other localities and from abroad) it has been produced by grinding nut-coal from the Silkstone pit of Altofts Colliery in a disintegrator. The composition and degree of fineness of the latter are as follows:—

		Intercepted by	
		100 mesh	7·25
Moisture...	3·21	... 150 ,,	7·50
Volatile matter	33·68	... 200 ,,	3·00
Fixed carbon...	57·60	... 240 ,,	9·25
Ash...	5·51	... Finer	73·00
	100·00		100·00

The quantity employed in an experiment is 1 lb. per linear foot, or 0·39 oz. per cubic foot of air-space. It is thrown on to the shelves by hand.

It is usually ignited by firing a charge of 24 oz. of gunpowder, tamped with 8 inches of dry clay, from a hole, 2 inches in diameter by 2 feet 9 inches deep, in a cannon, called the igniter, placed in the middle of the floor, pointing upwards at an angle of from 32 to 35 degrees, facing towards the mouth of the gallery and at a distance from it of anywhere between 260 and 360 feet, as the case may require. But when it is desired to take special pains to secure ignition, as, for example, when visitors are present, a second small cannon charged with 4 oz. of gunpowder and 3 inches of clay-tamping, placed at a point 90 feet nearer the open end than the igniter in such a position that it cannot ignite the dust, is fired first so as to raise a cloud of dust, which the air-current then carries inwards towards the larger cannon. Both cannons are fired electrically, the smaller one two seconds before the larger.

The discharge of the smaller cannon drives a cloud of dust 4 or 5 feet long out at the open end of the gallery; that of the larger cannon drives out a similar cloud between 30 and 40 feet long. Then comes a rush of dust, followed immediately by flame, which shoots out to an average distance of 156 feet, in some cases to 180 feet, accompanied by a loud report, which is said to be heard at a distance of 3½ miles. Finally, the flame rises up and ramifies into the cloud of coal dust which preceded its first appearance, now floating in the air above it, and a great volume of smoke and dust drifts slowly away.

In Fig. 2 the open end of the gallery is seen at the right-hand side; the white areas immediately in front of it and in the smoke-cloud represent the flame. Fig. 3 is a nearer view of the mouth of the gallery when an explosion is in progress.

All these phenomena, without exception, are identical, except as regards magnitude, with those produced with mixtures of coal dust and pure air, "without the presence of inflammable gas," in the Royal Society gallery in 1880–1, in the Prussian gallery at Neunkirchen in 1884 (see later), and in Hall's experiments in the Big Lady pit in 1890, all of which the present writer has seen, as well as the Altofts experiment.

On the other hand, the Altofts gallery is itself a mere toy compared to one of the galleries, 5300 feet, or nearly twenty times as long, in Altofts Colliery, through which the explosion sped in a straight line in 1886; and as the committee's own experiments, described in part ii., chapter ii., have shown that the pressure and velocity increase rapidly with the length strewn with coal dust, it seems somewhat absurd of the committee to propose to make minutely correct observations of pressure, velocity, temperature, the size, shape, and composition of particles of coked dust, and so on, with the idea that these observations will be of some practical value in solving questions relating to colliery explosions, which they rather indefinitely class under the far-reaching title of "chemical and physical phenomena."

A mine-waggon weighing 4½ cwt., placed on the rails at a distance of 6 feet inside the gallery, ricochets along the surface of the ground in front to a distance of several hundred feet when the explosion takes place. A similar experiment was witnessed by Sir W. Thomas Lewis and the present writer at the Prussian gallery at Neunkirchen, referred to above. The explosion itself is described in NATURE of November 6, 1884, p. 13, as follows:—"*Notwithstanding the entire absence of firedamp*, there was a true explosion of the most violent kind, and the clouds of afterdamp which streamed from every opening darkened the air in the neighbourhood of the gallery for two or three minutes."[1] A mine-waggon loaded with iron so as to weigh 15½ cwt., placed at the entrance to the gallery, was driven up an incline rising at an angle of 4° to a

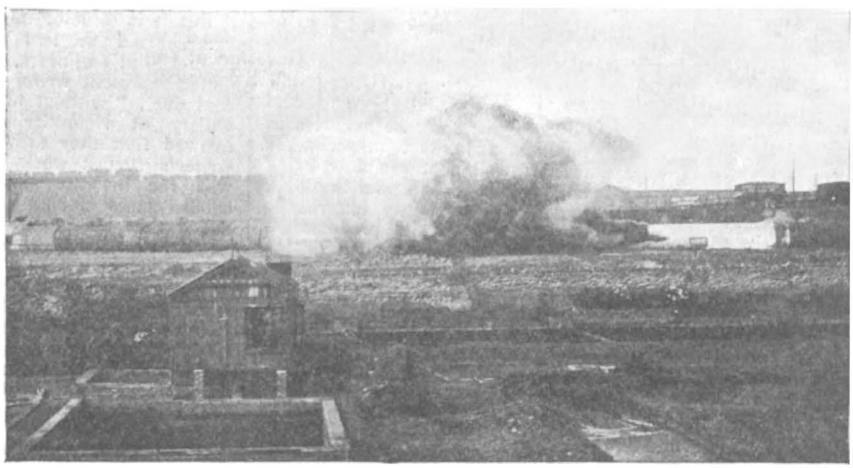

FIG. 2.—Flame issuing from Downcast End.

distance of 23 feet. The quantity of gunpowder used in the shot-hole was only 230 grams, or practically half a pound.

The observations (p. 21) regarding the position of deposits of coked coal dust on timbers fixed in the gallery to represent props in a mine are for several reasons, one of which is the baffling effect of the ventilating current, of no practical value as a means of throwing light upon the point of origin of an explosion in a mine.

Chapter iv., "On the Chemical Analysis of Coal Dust," and chapter viii., entitled "Laboratory Investigations," are intensely interesting and instructive, principally on account of the numerous, carefully thought-out devices described in the latter for obtaining, collecting, and analysing the volatile constituents of coal, and if published as a separate pamphlet would form a valuable addition to the library of everyone interested in the analysis of mineral fuels. The methods of estimating volatile matter, ash, and fixed carbon are practically the same as those recommended by Dr. Pollard in the Memoirs of the Geological Survey.[2]

In chapter v. the instruments intended "for investigating the mode of propagation of coal-dust explosions" (which, stated in plainer language, means those for measuring pressure, velocity, and temperature, and for

[1] The italics are the reviewer's.
[2] The Coals of South Wales (1908), p. 7.

collecting samples of the afterdamp), are described and illustrated. One of two methods of ascertaining velocity, which appears to be fairly satisfactory, consists in fixing strips of tin-foil, 4 inches long by ½ inch wide, in a horizontal position inside the gallery at intervals of 50 feet from each other, which, on being melted successively by the passage of the flame, break electric contacts in the same order, the results being recorded by an instrument of similar type to that usually employed for similar purposes.

The manometer is ingenious, and appears to work satisfactorily, but takes no account of negative pressure. It should be supplemented by adding another much more delicate instrument for the latter purpose.

No satisfactory instrument for recording temperature instantaneously has yet been devised. On the other hand, the contrivance adopted for collecting samples of afterdamp automatically is simple and efficient.

When there are obstacles in the form of "props and bars" (presumably of similar dimensions to the timbers employed for supporting the roof in the roadways of mines) fixed at a distance of 9 feet apart in the gallery, the pressure and velocity of the explosion are found to vary more or less directly with the length of gallery strewn with coal dust, through which the flame has to travel between the igniter and the mouth. In giving rise to greater frictional resistance, these obstacles apparently raise the pressure and temperature of the air advancing towards and rushing past them, and thereby promote a more rapid and intense combustion of the coal dust.

Two manometers, A and B, fixed at distances of 50 and 150 feet respectively from the mouth of the gallery, recorded the following maximum pressures per square inch when the point of ignition was at the respective distances from them shown in the following table:—

Number of experiment	B: Distance from igniter	B: Pressure	A: Distance from igniter	A: Pressure
	ft.	lb.	ft.	lb.
54	125	35	225	50
53	150	38	250	65
62	275	43	375	92

The highest pressure recorded, viz. 100 lb. per square inch, appears to have been in experiment 55, when a length of 150 feet next the mouth of the gallery was free from dust, the next following, 275 feet, strewn with dust, and the igniter was fired at the innermost end of the dust zone, that is to say, at a distance of 325 feet from the mouth, with presumably thirty-six sets of "props and bars" forming obstacles in the path of the explosion. The manometers were in the same positions as in the other experiments recorded above and below.

When there are no obstacles the pressures are much smaller, and appear rather to decrease than to increase with distance of travel, as shown below:—

Number of experiment	B: Distance from igniter	B: Pressure	A: Distance from igniter	A: Pressure
	ft.	lb.	ft.	lb.
50	125	11·9	225	8·75
51	150	9·8	250	8·3
110	275	8·5	375	9·2

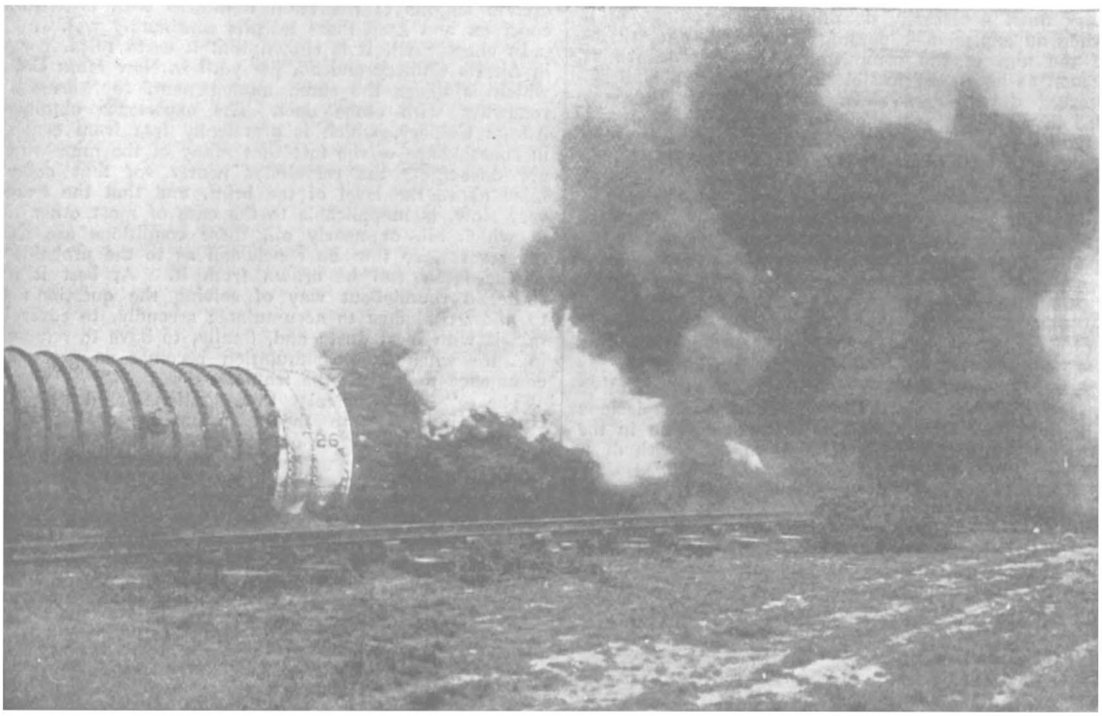

FIG. 3.—Flame issuing from the Downcast.

The records of velocity are as follows:—

First, with Silkstone coal dust and with obstructions in the form of "props and bars" in the gallery (pp. 155–6), it is stated that the velocity, between one contact-breaker 175 feet from the point of ignition and a second contact-breaker at manometer A (200 feet distant from the first) was 2014 feet per second in No. 62 experiment, and that between the point of ignition and a point 275 feet distant it was 475 feet per second in No. 53 experiment.

Secondly, with the same coal dust and without obstructions, the velocities between six points—the first at the igniter, the second 59 feet, the third 109 feet from the first, and so on, with an increase of 50 feet successively up to the sixth—were 39·7, 252·5, 72·5, 119·0, and 222·6 feet per second respectively.

Thirdly, with South African coal dust, and presumably with props and bars in the gallery, the velocities between five points—the first 12 feet distant from the igniter, the second 59 feet, the third 109 feet from the first, and so on, with an increase of 50 feet, as in the last case, up to the fifth—were as given below in feet per second:—

Number of experiment	1–2	2–3		3–4	4–5		Page
102	113·5	85·0	...	118·0	554·5	...	191
104	138·5	320·5	...	160·0	450·5	...	196
105	632·0	52·9	...	125·0	143·5	...	200

Considered as a whole, these results are so discordant that it is impossible to draw any other conclusion from them than that either the instruments are at fault or that there is some disturbing element at work, due, most probably to variableness in the quantity of dust suspended in the air in different sections of the gallery when the flame of an explosion is traversing it.

Owing to the very nature of the experiment, it is obviously impossible to provide that each section shall always contain the same quantity of dust, mixed with the same degree of uniformity in the air which occupies it, at the instant an explosion is passing through it. It is equally obvious that, unless that condition can always be rigidly complied with, the results cannot be concordant as between one section and another, although the sum of the results may seem to be fairly uniform when one explosion is compared with another. But the same absence of uniformity must necessarily obtain in the workings of a mine when an explosion is passing through it, and, therefore, if the aim of the committee is to reproduce that phenomenon as nearly as possible in their artificial gallery, the observed discordances show that they have already succeeded in doing so.

The haulage roads, along which the coal is conveyed from the working places to the shaft, contain larger quantities of very fine coal dust than any other parts of a mine, and ever since the time when the coal-dust theory of great explosions was first propounded,[1] they have been recognised as the routes along which explosions, commenced at any point in a mine, travel to every other part of the workings, however remote. This was well exemplified in the plan which accompanied the description of Penygraig Colliery explosion[2] (1880), previously referred to. It has also been recognised, of course, that if coal dust could be prevented from accumulating in the roadways, or be rendered innocuous by water or other means, the range and disastrous effects of explosions would be greatly limited. To prevent accumulation in the first place by the employment of mine-waggons with dust-tight bodies, *filled only to the brim and provided with covers*, is obviously the best possible expedient that could be adopted, and would be infinitely preferable to the present careless system of carrying the coal in all sorts of leaky or over-loaded waggons, from which it dribbles or falls upon the roads, and is then ground or trodden into the very dust which constitutes the danger.

Under existing conditions, as regards the mode of construction of mine-waggons, the production of coal dust is inevitable; and although there is no legislative enactment in this country compelling the mine-owners to do so, many of them already water the dust in their haulage roads once or twice a day in order to render it innocuous. But in many other mines water cannot be used for this purpose, as it causes the ground above or below the seam to swell or fall to pieces, and consequently the dust is allowed to remain dry. It has been proposed to give the owners of the latter class of mines the alternative of rendering the dust innocuous by covering it from time to time with inert dust, or with a hygroscopic or other salt. The committee have, accordingly, directed their attention to the question of using inert dust for this purpose, and made careful experiments, which are described in chapters vi. and vii., to ascertain, first, the effect that dust of this nature has in arresting the progress of an explosion, and, secondly, the cost of applying it practically in Altofts Colliery.

The inert dust for both purposes has been prepared by grinding the roof-stone of one of the seams of Altofts Colliery in a roller-mill at a cost of 2*s.* per ton.

In the five following experiments a standard length of 275 feet of the gallery was strewn with coal dust, the igniter was fired at the inner end of this zone, and the space at its outer end, 150 feet in length, was treated as follows:—

[1] Proc. Roy. Soc., vol. xxiv., p. 354 (1876).
[2] *Loc. cit.*

Number of experiment	Left dustless or strewn with stone dust or coal dust			Pressures recorded by the manometers	
	Dustless ft.	Stone dust ft.	Coal dust ft.	B lb.	A lb.
55	150	—	—	40	100
57	—	150	—	40	9
58	—	100	50	31	17·5
62	100	—	50	39·5	84
116	—	100	50	33·7	9·18

In experiment 55 the flame passed just beyond the outer end of the dustless zone; in 57 it penetrated 55 feet into the stone-dust zone; in 58 it penetrated 54 feet into the stone-dust zone; in 62 it passed through the dustless and coal-dust zones, and shot out 100 feet beyond the latter; in 116 it penetrated 22 feet into the stone-dust zone.

These experiments show that a zone of stone dust is more efficient in arresting an explosion than a dustless zone, and thus help to answer, but do not completely solve, one of the questions still being considered by the Royal Commission on Mines, as to whether it is desirable to compel the owners of mines in which water cannot be employed for the purpose of laying the dust to surround certain lengths of the main roadways with brickwork or concrete, and keep these lengths continually wet.

In chapter vii. it is shown that it costs 1·85*d.* per yard in Altofts Colliery and 2*d.* per yard in New Moss Colliery, which is under the same management, to "dress" the roadways with stone dust. The experience obtained in Altofts Colliery, which is practically free from coal dust, in consequence of the fact that many of the mine-waggons are dust-tight, the remainder nearly so, that none are filled above the level of the brim, and that the traffic is very slow, is inapplicable to the case of most other mines in which all, or nearly all, these conditions are exactly the reverse, so that no conclusion as to the probable cost in the latter can be drawn from it. At best it seems rather a roundabout way of solving the question: first, to allow coal dust to accumulate; secondly, to cover it or mix it with inert dust; and, finally, to have to remove the mixture when the accumulation becomes so great as to commence to impede the traffic.

The "Microscopical Investigations" described in chapter ix. refer to the microscopical examination of grains and aggregations of coked coal dust, grains of other matter, and fragments of fibrous substances that have been subjected to a high temperature, and are accompanied by twenty full-page beautifully coloured illustrations, which remind one more of a birds'-egg book than of a serious treatise relating to a subject connected with mining. It is not easy to see how these investigations are likely to affect the question one way or another, but possibly the committee may be able to extract some information from them that does not appear on the surface.

Chapter i. of part ii., written by Dr. Wheeler, the accomplished chemist and physicist attached to the testing station, entitled "The Mode of Propagation of Coal-dust Explosions: Introduction," purports to "record the main facts that have been established regarding the mode of propagation of coal-dust explosions," but does not deal with anything specially new or original.

The second chapter of part ii., and the appendix on "Experiments with Welsh, Scotch, and South African Coals," have been already referred to so far as seems to be necessary in the present place.

The volume concludes with lists of the illustrations and plates, and an index to the subjects, and is, as a whole, most creditable to the publishers. W. GALLOWAY.

EXPLORATIONS IN NEW GUINEA.

AT the meeting of the Royal Geographical Society on January 30, Dr. H. A. Lorentz gave an account of his latest journey in New Guinea, in the course of which he succeeded in reaching the snow-covered peaks of the main range. Much interest attaches to those regions in the tropics where perpetual snow occurs, with their transitions from the luxuriant vegetation of the equatorial zone to the scanty flora of the snow-line, which on the slopes of Wilhelmina Peak was reached at an altitude of