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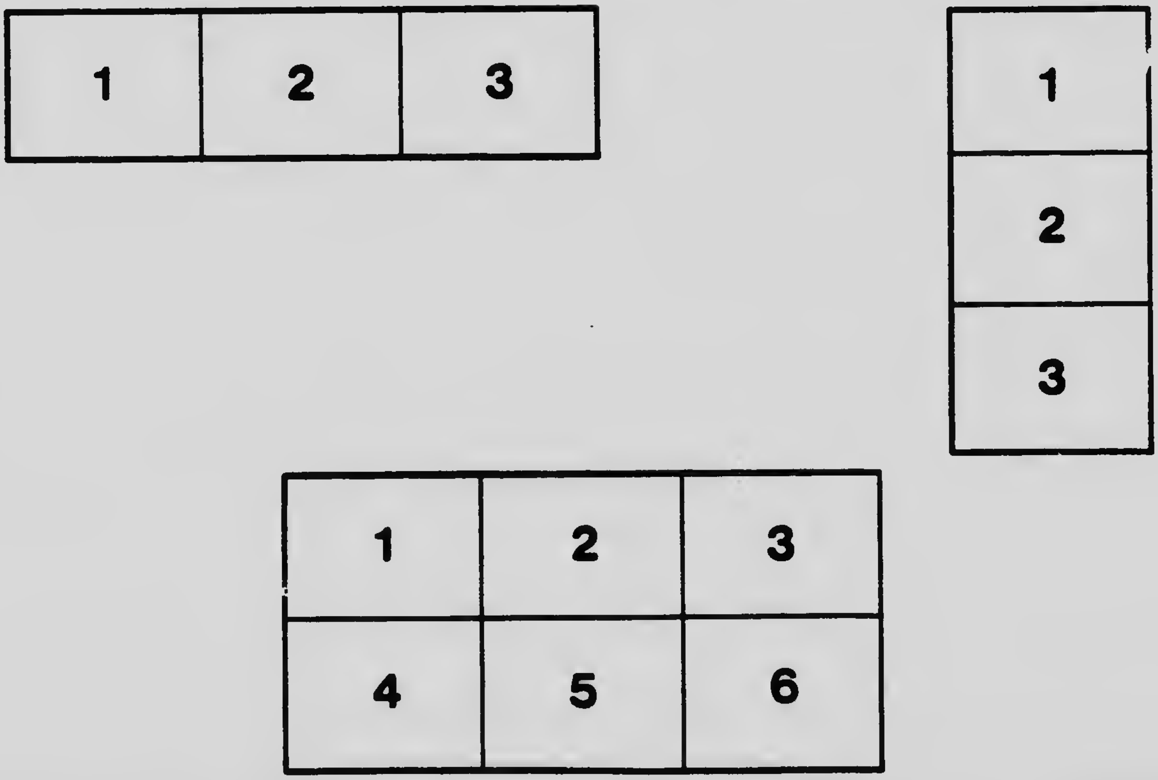
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BRITISH COLUMBIA

DEPARTMENT OF MINES

HON. WM. SLOAN, Minister.
R. F. TOLMIE, Deputy Minister. W. FLEET ROBERTSON, Provincial Mineralogist.
GEO. WILKINSON, Chief Inspector of Mines.

BULLETIN NO. 2, 1918

BUMPS AND OUTBURSTS OF GAS

IN THE MINES OF

CROWSNEST PASS COALFIELD

REPORT BY

GEORGE S. RICE, E.M.
Chief Mining Engineer, U.S. Bureau of Mines.

PRINTED BY
AUTHORITY OF THE LEGISLATIVE ASSEMBLY.

VICTORIA, B.C.:
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1918.

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R. F. Tolmie, Deputy Minister. W. Fleet Robertson, Provincial Mineralogist.
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OFFICE OF CHIEF MINING ENGINEER,
U.S. BUREAU OF MINES,
WASHINGTON, D.C., March 1st, 1917.

Hon. William Sloan,
Minister of Mines, Province of British Columbia,
Victoria, B.C.

DEAR SIR,—I have the honour to submit the accompanying report of my investigations into the causes and possibilities of avoidance in future of the disastrous "bumps" which occurred in the year 1908 and recently in November, 1916, in the Coal Creek mines of the Crowsnest Pass field; and incidental to that inquiry, what precautions might be taken in regard to outbursts of gas.

In response to a request for my services made by your Department to the Director of the United States Bureau of Mines, I was detailed to undertake the investigation, and accordingly arrived at Fernie, B.C., on December 2nd, 1916. There I was met by W. F. Robertson, Provincial Mineralogist; Thomas Graham, Chief Inspector of Mines for the Province; T. H. Williams, Inspector of the Coal Creek District; and George O'Brien, Inspector of the Michel District. These gentlemen, during the two weeks of my investigation, accompanied by the officials of the different mines, and at times by W. H. Wilson, general manager of the Crow's Nest Pass Coal Company, escorted me in and about the mines at Coal Creek and Michel, explaining the mining conditions and methods, the nature and circumstances surrounding the occurrence of the "bumps" and outbursts of methane or fire-damp.

I am also indebted to W. H. Wilson, general manager, and the various officials of the Crow's Nest Pass Coal Company, the only company now operating in the main Crowsnest field, for the courtesies extended during my investigation. Every facility was offered in visiting the mines, in obtaining information, and the services of the efficient engineering department of the company were freely given for the preparation of maps, sections, and other data.

Before leaving Fernie I drew up a preliminary report, copies of which I handed to Messrs. Robertson and Graham, so that there might be no delay in presenting my views to them as to the dangers threatening and precautions already taken at the initiative of the mining company, as well as by order of the Chief Inspector of Mines. This report recommended that permission be given to the company to reopen and use certain entries in the No. 1 East mine passing through the area most seriously affected by the "bumps" and in which work had been temporarily prohibited by Mr. Graham.

The general conclusions given in the preliminary report, which in the main features are adhered to in this report, were arrived at after many conferences locally with those best qualified to give explanations of the phenomena encountered in the past and suggestions concerning the geologic and other natural conditions found in mining, together with the best means of meeting the difficulties.

Suggestions of special importance were received from Messrs. Robertson and Graham, and General Manager W. H. Wilson, the latter showing breadth of vision in the consideration of future work and methods of overcoming difficulties, and rendering my task far easier, by presenting a plan of future workings of the Coal Creek mines on the south side of the valley that met practically every suggestion that I had to make in the matter of safety in working.

During the investigation many samples of gas and coal, as well as of coal-dust, the latter for determining the explosibility hazard, were taken and sent to the Bureau of Mines Laboratory at Pittsburgh for analysis and special testing. These laboratory investigations, some of which involved special methods of handling, have now been completed and show some most interesting results, and should my recommendation for a permanent commission for continuing the investigations into the geophysical and mining conditions of the Crowsnest field be carried out, would be very suggestive of certain lines of further investigation.

I trust that this report may be of value in helping to point out what may be done to make mining safer in the Crowsnest coalfield, which is of such great importance through its extensive fuel resources to the Province of British Columbia and the adjoining regions.

Very respectfully yours,
GEORGE S. RICE.

REPORT ON

BUMPS AND OUTBURSTS OF GAS

IN THE

CROWSNEST PASS COALFIELD.

Summary of Principal Findings contained herein.

The Crowsnest field is regarded by Canadian geologists as the most important coalfield in British Columbia.

This field presents unusual natural difficulties, because the coal-beds are at the base of an elevated plateau; it is impossible to reach the coal except through outcrop; the coal is also under a heavy load requiring great care in mining to prevent squeezes and "bumps."

The coal-beds are very gaseous; that is, they have large methane (fire-damp) flows at Coal Creek and Michel; and at Morrissey outbursts of gas occur unequalled except in certain mines in Belgium.

"Bumps" are not related to gas-outbursts, but they may occur, as in the State of Washington and in Great Britain, where the overlying rocks are rigid and there is great weight of cover, and when mining has either extracted too much coal in advance mining or it has not been taken out completely, starting from the outcrop, which would break the overlying rock in successive slices and thus prevent "bumps."

"Bumps" are believed to be caused by the subsidence of the roof in certain areas under rigid rocks, leaving a great unsupported span of rock stratum. When one of these has given way it means the hammer-like blow of thousands of tons of rock striking on the immediate roof or flexible stratum overlying the mine, which imparts the blow downward, breaking timber, causing extensive falls in the mine, and sending rock-tremors through the strata.

Improper mining in No. 2 mine was the cause of "bumps" in that mine in 1907-8, and in turn the subsidence over this area affecting the strata higher up caused the recent "bumps" in No. 1 mine.

"Bumps" may occur in future over the same area, but, it is probable, with decreasing force, as the rock stratum broken down in each case has less distance to fall, less load, and is more distant in height above the mine.

If the measures proposed are carried out—viz., of taking out less than 15 per cent. of coal on the advance and taking down the rash and roof coal in the working places in No. 1 mine—there is comparatively small danger to life for the men employed underground.

To give warning of impending outbursts of gas in certain dangerous zones with the advance of the working-places, long drill-holes should be kept drilled in advance.

To provide for the large regular flows of methane, well-kept-up airways of large area and powerful fans should be employed, with ample margin of capacity.

A permanent commission should be formed to further investigate and review the evidence collected by members of the commission, the Inspectors of Mines, and others, having among its membership a geologist, a mining engineer, a chemist, and an experienced mine operator.

General Statement about "Bumps" in Coal Creek Mines and Call for Investigation.

During the years 1906 to 1908 a series of "bumps," causing loss of life, occurred in the No. 2 mine at Coal Creek in the Crowsnest coalfield of British Columbia. Prior to this, "bumps" had been noted, but had not been considered serious. In January, 1907, the first loss of life occurred through a "bump," and after that time others occurred of increasing intensity, until on July 31st, 1908, four men were killed and twenty others temporarily entombed and narrowly escaped suffocation from gas. A great volume of gas was liberated by the "bump," accompanied by breaking-down of return overcasts and complete blocking of the main entry for 600 feet. This disastrous "bump" caused the mining officials of the Province to set off a district in the No. 2 mine in which working was prohibited on account of the dangers from the "bumps."

As a further result a change was made in the system of mining, under which less than 25 per cent. of the coal is taken out, the balance to remain in pillars until the selected boundaries have been reached and the retreating work begun. The No. 1 East mine had then been started in the so-called No. 2 bed, lying about 150 feet vertically above No. 2 mine. It had been opened out unsystematically along the outcrop, but a change of plans was made, and the mine was developed on systematic lines, with narrow rooms and large pillars. The mining development was vigorously pushed from 1907 to the present, until the area of workings covered and extended beyond the area over the abandoned, prohibited district of the No. 2 mine.

Everything proceeded nicely, except for the large flows of methane encountered in the development of the mine, until 1916, when, without preliminary warning, on the nights of November 7th and 8th, three "bumps" occurred, the first two somewhat local in effect, but the third of tremendous force, which broke down timber and shook down falls of roof through a large part of the active mine-workings. It caused earth-tremors which were felt for miles, not only in Fernie, five miles away, but in other towns to the north and south of Fernie. This was all the more extraordinary as Fernie lies on a great shale-bed underlying the coal-measures.

In spite of the intensity of the "bumps" and the great destruction in the workings, only one man was killed. This death resulted from the second "bump"; several men were badly bruised in the third great "bump," and some of the escapes of the men in the mine were almost miraculous on account of the great area of roof which had fallen. Had this great "bump" occurred during the day shift the loss of life could not but have been very great, as areas in the rooms and entries through the most active working section, aggregating thousands of feet in length, were heavily caved.

A fourth, milder, and more local "bump" occurred on November 13th, and, after the investigations here reported, another "bump" of considerable severity occurred on January 12th, 1917, according to communication from Mr. Graham, affecting the west return airway for several hundred feet outby the No. 11 West. Lesser "bumps" not causing violent vibrations are heard from time to time, the sound being like a heavy knock or a distant blast.

As a result of the "bumps" of November 7th and 8th, the operating company, the Crow's Nest Pass Coal Company, and the Department of Mines of British Columbia were deeply concerned for the immediate and the future safety of the mine, especially on account of the danger to the mine-workers. Accordingly, Thomas Graham, Chief Inspector of Mines, temporarily prohibited work in certain large areas of the No. 1 East mine (inby the No. 10 East and No. 10 West). The writer was invited by the Minister of Mines, through the Director of the United States Bureau of Mines, to investigate and report upon the nature of the "bumps," and, if such are unavoidable, how danger to the underground workman might be minimized. The invitation being accepted, the writer journeyed to the Crowsnest field and investigated, in December, 1916, several Coal Creek mines and the Michel mines, at the north end of the field. He inspected practically all accessible workings, arranged the taking of samples of gas, coal, and of coal-dust, and the drilling of test boreholes in advance of, or at the side of, selected working-places to determine the gas-pressures. He conferred with all the mining men who could throw light on the problem, especially W. R. Wilson, General Manager of the Crow's Nest Pass Coal Company; W. F. Robertson, Provincial Mineralogist; Thomas Graham, Chief Inspector of Mines of the Province; T. H. Williams, Inspector of the Coal Creek District; G. O'Brien, Inspector of the Michel District; and many mine officials of the company. He is greatly indebted to all of those named for the information secured for this report—to Mr. Michell, Mining Assistant to Mr. Graham, who took charge of the sampling, also of the test boreholes drilled to obtain gas-pressures, and to A. C. Fieldner, Chemist of the United States Bureau of Mines, who made analyses and who developed a new method of testing coal samples for the amount of occluded gases given off in crushing the coal.

NATURE OF BUMPS AND OUTBURSTS.

Before proceeding to a more detailed statement of the phenomena of "bumps" and "outbursts" in the Crowsnest field it will be well to define what is meant by such terms, both as applied in the Crowsnest field and in other mining districts of the world. W. F. Robertson, in his report on "bumps" in the Crowsnest coalfield, published in the Annual Report of the Minister of Mines for 1908, stated:—

"The term 'bump' is somewhat descriptive of the sensation produced by their occurrence a certain distance away—a sudden jarring of the mine, produced by the sudden giving-away or cracking of the strata above or below the coal-seam."

Thomas Graham, at a meeting of the Mine Inspector's Institute of the United States of America at their Joplin, Missouri, meeting on June 13th, 1916, in an instructive paper entitled "Some Gaseous Mines in the Crowsnest Pass Coalfield," states:—

"The term 'bumps' is a somewhat local expression used to describe the ominous signs that betoken the movement of the strata overlying the several seams operated in the Crowsnest Pass coalfield. These 'bumps,' although accompanied by more or less heavy discharges of gas, are not in the nature of outbursts of gas and coal described." (Mr. Graham had described outbursts at the Morrissey Colliery.)

It is to be noted that the recent (November, 1916) "bumps" in the No. 1 East mine were not accompanied by outbursts of gas. Miners sometimes use the term "bump" to designate small disturbances local in their nature, due apparently to issuance of gas at the face of the mine, accompanied by loud cracking or knocking sounds in the roof or in the face-coal which may be thrown down. "Bumps" are not confined to the Crowsnest field; apparently the term originated in Great Britain, as violent "bumps" occur frequently in mining the 10-yard seam of South Staffordshire, the writer was informed in visiting that district in 1908, and evidently had been known for years. "Bumps" occur in the Carbonado mines in the State of Washington, also in the Sunnyside mines of Utah. The characteristic features in common are thick or deep cover over the coal-bed, and this cover contains a series of massive rigid rocks like conglomerates or massive sandstones.

It therefore seems best to apply the term "bump" to designate the very violet effect produced by profound rock-movements resulting in earth-vibrations, which on a large scale would be called an earthquake. The effects are quite different from those produced by "outbursts" of gas, mine "squeezes," or "falls" of insufficiently supported roof. The two latter phenomena, as well as "bumps," may or may not be accompanied by release of gas. On the other hand, "outbursts" of gas themselves are not productive of earth-vibrations. Accordingly, it seems wise to distinguish between the phenomena mentioned, although both "outbursts" and "bumps" have this in common, that of great thickness of cover over the coal-bed.

AIR-BLASTS.

That gas contained in the strata under high pressure is not a cause of "bumps" is indicated by the non-occurrence of "bumps" as an accompaniment of gas-outbursts which occurred in the Morrissey collieries, described by Mr. Graham in the paper referred to. Nor are "bumps" reported in the mining regions which are subject to disastrous "outbursts," for example, of methane in the Belgian coalfields and of carbon-dioxide gas in mines in a certain coal-basin of Central France.

On the other hand, in certain metal-mines which do not give off any gas when great depth is attained, as in the deep Lake Superior copper-mines, and the deep gold-mines of South Africa and elsewhere, serious "air-blasts" have occurred of a nature very similar to "bumps."

CROWSNEST COALFIELD.

The Crowsnest coalfield is spoken of by Mr. Dowling in Memoir 59, "Coal Fields and Coal Resources of Canada" (excerpt from "Coal Resources of the World," published under the auspices of the Twelfth International Geological Congress), as being "*the most important body of coal that is being mined in the Province.*" It is an elevated trough, narrow at the north end and wide at the south, the southern part broadening toward the south-east. (*See* Exhibit 1, which is Plate VI. from atlas accompanying the "Coal Resources of the World.") The extreme length north and south is thirty-five miles, and the greatest width along the southern half, a little south of Coal Creek, is thirteen miles. There are also some outlying patches of coal in high mountains farther to the east. The field covers 230 square miles, and is estimated to contain, according to a report issued on "Coal Resources of the World," in seams over 1 foot thick, 22,595,000,000 tons of bituminous coal in "actual reserve," 20,750,000,000 tons in "probable reserve," and 2,160,000,000 tons in beds 2 feet thick and over at depths greater than 4,000 feet and less than 6,000 feet, which might be expressed by the term "possible reserves"; this making the total reserves 45,505,000,000 tons.

SECTIONS OF COAL-MEASURES.

Number of Seams over 1 Foot Thick, Aggregate Thickness of Coal and Thickness of Coal-measures in Three Typical Sections.

Locality of Section.	Number of Seams.	Total Thickness of Coal.	Thickness of Coal-bearing measures.
		Feet.	Feet.
Morrissey	23	216	3,676
Fernie	23	172	2,250
Sparwood—			
Upper measures	23	173	2,050
Lower measures	24	43	2,015

The data regarding the Crowsnest Coalfield was obtained from Memoir No. 59, "Coal Fields and Coal Resources of Canada," prepared by D. B. Dowling, of the Geological Survey of Canada, for the Twelfth International Geological Congress, and from Thomas Graham's paper, "Some Gaseous Mines in the Crowsnest Pass Coal Field," also from some personal observations in the vicinity of Coal Creek and Michel.

A number of seams are too thin and too impure to mine with commercial success at the present time, and it is considered that the available coal does not have an aggregate thickness, in beds over 3 feet thick, of more than 100 feet. Some of the thickest beds, 10 to 20 feet thick, owing to friability of the coal and poor roof, cannot under present conditions be cleanly mined out, and there is in consequence much loss of coal.

Most of the marketable coal-beds are in the lower part of the coal-measures, which, geologically speaking, are in the Kootenay formation of the Lower Cretaceous series. The Fernie shales, 2,000 feet thick, underlie the Kootenay formation, but there appears to be some doubt whether these shales belong to the Lower Cretaceous or the Jurassic.

The Crowsnest basin has been buckled into a north-and-south synclinal trough by the great dynamic forces pressing from either side (east and west) in the uplifting of the Rocky Mountain ranges. As a consequence, around the edges of the basin the beds have been steeply uplifted. (*See* photograph, Exhibit A.) While the more rigid sandstones and conglomerates overlying the more important coal-seams have protected the latter, there is abundant evidence of thrust under the capping rocks acting laterally on the coal-beds along the margin of the field and squeezing the coal in some places to increased thickness and badly crushing it. There is evidence also of a general lateral movement which has taken place in the plane of the No. 1 coal-bed, as demonstrated by a slickensided and rolled shale-band in the upper part of the coal-bed. Also there has been some local faulting and buckling of the coal-beds, which causes much difficulty in mining operations.

The anticlines produced on either side of the coal-basin by the profound east-and-west thrusts have been deeply eroded and valleys thus formed. This has led to the basin, protected by the overlying hard sandstones and conglomerates, becoming an elevated plateau.

The Elk river runs along the west side, in the Fernie shales. The elevation of the Elk River valley above sea-level at Sparwood, near the north end of the field, is 3,637 feet; at Fernie, 3,365; and at Morrissey, opposite the south-west corner of the field, is 3,101. Along the east side of the plateau the elevation of the valleys is from 4,000 to 5,000 feet. The escarpment of the plateau is from 6,000 to 7,000 feet above sea-level, the highest points rising from 300 to 400 feet above this.

The dips of the coal-beds from the edges of the basin probably carry the lowest beds down, in the middle of the trough, the depths where under the higher ridges there is from 3,500 to 5,000 feet of cover above the lower beds. Over the present advance workings of the Coal Creek mines the maximum cover is from 2,000 to 2,500 feet thick (*see* vertical cross-sections prepared by the coal company engineers, Exhibits 2 and 3), consisting largely of massive sandstones and conglomerates in the upper part. The outcropping rocks form bold escarpments skirting the valleys and sharp projecting spurs. (*See* photographs A to E.)

DESCRIPTION OF COAL-BEDS.

The coal-beds in any one locality are well defined, but it is difficult to carry the identification from one locality to another, because the coal-beds change their characteristics and the immediate rocks, shales, and sandstones lack distinctive features. The coals in the different beds that have been worked at Coal Creek, Hosmer, and Michel do not differ much in chemical composition and are coking-coals, but the coal at Morrissey had evidently been subjected to more intense crushing and the percentage of fixed carbon is higher. As only the Michel and Coal Creek mines could be entered, the description of the coal-beds now mined will be limited to these.

Michel Coal-bed Sections.—The principal bed mined at Michel is intersected by a fault parallel with the strike of the beds. Its section is as follows:—

Sections of Coal-bed No. 3 East, Michel Colliery.

Above Big Fault. Hard Rock Roof.		Below Big Fault. Hard Roof.	
Cap-rock	1′ 6″		1′ 6″
Coal	2′ 6″		4′ 0′
Shale (mining)	0′ 8″	(Bone)	0′ 6″
Coal	3′ 0″		3′ 0″
Rock	0′ 2″	(Rock, hard)	1′ 2″
Bone and coal	0′ 9″	(Shale)	0′ 6″
Coal	3′ 6″		
Shale	1′ 5″		6′ 0″
Hard rock floor — Coal, net thickness	9′ 0″		13′ 0″

Old No. 3 mine, Michel Colliery, which adjoins the foregoing, works two beds, with an interval of 110 feet between. The upper one, which is understood to correspond with the bed worked in No. 3 East, attains a thickness of 16 feet of coal.

Coal Creek Coal-bed Sections.—A general section showing six seams which have been more or less prospected are best shown in the sections east to west and north to south at the Coal Creek Colliery (Exhibits 2 and 3). Of these, only Nos. 1 and 2 have been found to be commercially minable at present. Normally these beds are from 75 to 150 feet apart, but in a certain "crumpled zone" (*see* map, Exhibit 4) in the west parts of No. 1 East mine and No. 2 mine the beds come together.

Section of No. 2 Coal-bed.

Roof, strong shale, in some places sand, shales, and sandstone.	
Coal	3′ 6″ to 8′ 0″
Rock with streaks of coal	1′ 8″
Coal, high in ash (gaseous)	1′ 4″
Floor, shale.	

Section of No. 1 Coal-bed.

(75 to 150 feet above No. 2 bed.)

Main roof, massive shale and sandy shale.	
Roof, coal clean, friable	2′ 6″ to 3′ thick.
Rash, slickensided shale with coaly layers	1′ to 4′ „
Coal, columnar structure, soft, clean	9′ to 13′ „
Floor, shale (strong).	

KIND OF COAL IN CROWSNEST FIELD.

The Crowsnest field produces a good grade of bituminous coal, the different beds in any one locality having about the same kind of coal. Except at Morrissey, where the fixed carbon is too high to permit making coke in bee-hive ovens, the coal makes a good metallurgical coke. There are 440 ovens at Fernie coking Coal Creek coal, and 480 at Michel.

Following are analyses of the coals produced by different collieries, as given on page 116 of Memoir 59:—

Analyses of Samples taken in Coal Creek Mines, December 1st to 13th, 1916.

Colliery.	Moisture.		Proximate Analysis of Dried Coal (Moisture-free).			Dried Coal.	
	Mine Basis.	Air-dried Basis.	Volatile.	Fixed Carbon.	Ash.	Sulphur.	B.T.U.
Michel—							
No. 3	1.4	0.4	24.8	62.7	12.5	0.5	13.270
No. 7	1.9	0.7	22.0	65.5	11.9	0.4	13,360
No. 8	3.0	1.1	24.1	65.7	10.2	0.6	13,480
Hosmer—							
No. 2	1.7	0.9	21 3	63.4	15.3	0.3	12,710
No. 6	2.6	1.1	25.0	62.0	12.4	0.6	13,090
No. 7	4.0	1.3	28.0	64.5	7.5	0.6	13,990
Coal Creek—							
No. 2	2.2	1.3	26.3	64 7	9 0	0.5	13,820
No. 5	1.0	0.5	24.0	65.2	10.8	0.5	13,480

The samples were taken in certain places in the Coal Creek mines by Mr. Michell, under the direction of the author, and analyses made at the United States Bureau of Mines Laboratories at Pittsburgh by A. C. Fieldner, chemist. The samples were gathered at the respective points, ten in all, and immediately placed in tight jars (Mason jars). On reaching the Pittsburgh laboratory they were treated in one of two ways: Three samples were analysed for moisture as received, moisture when dried, volatile matter, fixed carbon, and ash; also the calorific value was determined. The other seven were opened under water to determine the amount of gas that had been given off since gathering; hence the moisture as received could not be determined, but the other components were determined, as in the first lot. While the jars had rubber gaskets and were wrapped with insulating-tape, it was evident that gas in each case had escaped in transit, as in all cases gas and air in mixture in the cans was at atmospheric pressure.

The samples were not taken by the standard method of sampling by picking a groove from top to bottom of the coal-face, but by gathering nut-sized pieces from top to bottom. This was done to obtain sampling for testing for occluded gas at the laboratory, but there is some question if such a sample is an average of the face at the respective points of sampling in the matter of ash content, but it is not probable that there is any essential difference in the ratios of the other constituents.

The special purpose in taking these samples was to determine, in conjunction with a series of road-dust and rib-dust samples taken at the same time, the explosibility of the coal-dust found in the Coal Creek No. 1 mine. Also for this purpose a large 3½-ton sample of coal was obtained from the face of the mine and shipped to the experimental mine at Bruceton, Pa., where it was crushed, pulverized, and tested. Similar coal-, rib-, and road-dust samples were sent from the Nanaimo mines, Vancouver Island, B.C. The results obtained in the tests form the subject of special reports to the Chief Inspector of Mines of British Columbia by the United States Bureau of Mines.

Face Section Samples, Coal Creek Mines.

Colliery.	Location in Mine.	Can No.	Lab. No.	Moisture, Mine Basis.	Proximate Analysis (Air-dried).				Dried Coal.	
					Moisture.	Volatile.	Fixed Carbon	Ash.	Sulphur.	B.T.U.
Coal Creek—										
No. 1 E....	Face, 10 East......	3	27155	1.08	0 50	23.25	63 60	12.65	0.31	13.529
No. 1 E....	Face, 1 N...	5	27157	1.58	0.50	21 35	65.05	13 10	0.34	13,462
No. 3......	Face, Main level ...	16	27158	1.12	0.70	24.05	66 05	9.20	0.57	14,081

Face Section Samples, Coal Creek Mines—Concluded.

NOTE.—As the following samples were used for making occluded gas determinations, the moisture was not determined.

Colliery.	Location in Mine.	Can No.	Lab. No.	Proximate Analysis (Air-dried).				Dried Coal.	
				Moisture.	Volatile.	Fixed Carbon.	Ash.	Sulphur.	B.T.U.
Coal Creek—									
No. 1 E.....	Face, No. 22 room, 10 E..	2	27154	0.55	24.78	65.17	9.50	0.31	14,047
No. 1 E.....	Face, No. 1 room, 9 E..	4	27156	0.40	24.23	66.52	8.85	0.32	14,063
No. 3.......	Face, No. 2 incline......	17	27159	0.55	28.52	63.83	7.10	0.54	14,319
No. 2.......	Face, Main level.........	18	27160	0.55	27.17	70.28	2.00	0.41	14,260
No. 2.......	Face of E. slope..........	19	27161	0.45	26.99	68.46	4.10	0.45	14,879
No. 1 S.....	Face of Main level........	20	27162	0.45	27.80	65.35	6.40	0.27	14,602
No. 1 S.....	Face of No. 5 incline......	21	27163	0.60	26.86	67.84	4.70	0.33	14,837

NOTE.—The above samples are reported on a slightly different basis than the previous analyses quoted from the Canadian Survey Report, in which the coal was reported on a moisture-free basis. The above analyses are on air-dried basis.

GASES GIVEN OFF BY COAL-MEASURES.

It is a normal condition in deeply bedded coal to find hydrocarbon gases both in the coal itself and in the enclosing rocks. There is, however, the widest difference in the amount of gas encountered by mining in the various coalfields, and almost as great a difference between different beds in certain coalfields. Some coal-beds are considered non-gaseous, although practically every bed gives off a little gas, but unless it gives it off fast enough to accumulate as a body of gas it is usually rated as non-gaseous.

Gas is held in the strata in two ways:—

(1.) A filling of the pores of the crevices, cracks, and bedding-planes under more or less pressure, so it is given off rapidly when it is liberated by the advance of the mine-workings, or where it occurs in a roof stratum when the roof material breaks down, or there is a slip which intersects a main slip, crevice, or roof-joint in which the gas may be stored under pressure.

(2.) The other form is stored in cells of the coal and is commonly known as "occluded" gas. Such gas is liberated slowly when the coal is broken, and with each crushing of the coal more gas is liberated. With some kinds of coal there is comparatively little gas released; in other coals there is a large amount. Generally, when there is a large amount of so-called "occluded" gas, the crevices and cracks of the strata are also charged with gas.

The amounts of gas thus held in the coal, which for want of a better term will be called "occluded" gas, in different districts has been summarized in Bulletin 72 of the United States Bureau of Mines, by N. H. Darton, entitled "Occurrence of Explosive Gases in Coal Mines."

In many of the investigations which have been made to determine the amount of gas given off by broken coal, the coal has been heated. This is not a proper method of determining, as then there is more or less destructive distillation. When the tests have been made using atmospheric pressures, the volume of gas from a unit of coal has been found to vary from one-half to one and a half times the volume of the solid coal. When finely crushed and kept standing for six months, anthracite coal gave off 1.83 of gas, chiefly methane. For shorter periods the quantity given off was very much less than one volume. This Chamberlain found to be true of other coals, so that in comparing one kind of coal with another the question of size of crushing and length of time seems to be an important factor. It is necessary to know the procedure followed by experimenters in making comparison of results, since as yet there has been no standardization of method.

OCCLUDED GAS IN COAL FROM COAL CREEK MINES.

A series of special samples of nut or egg size were taken in the Coal Creek mines in different headings and rooms, put into Mason jars at the point of sampling, sealed, and sent to the Bureau of Mines, Pittsburgh Laboratory. Ten samples were taken, Laboratory Nos. 27154 to 27163, inclusive, and on reaching Pittsburgh seven of them were opened under water and were found to contain from 0.06 to 0.25 volumes of methane per volume of coal. There was a little carbon dioxide, and it will be noted in the analyses given in the table, which follows later, that there was little oxygen. That sealed in with the coal had largely been absorbed by the coal.

It is evident from a study of the gas analyses that there was escape of gas from the containers; oxygen plus carbon dioxide is much lower in ratio to the nitrogen than should be the case. The gases in the cans on arrival were found to be at atmospheric pressure.

METHOD OF GRINDING THE COAL IN VACUO.

Tests were made on one of the samples from Coal Creek, Can No. 16, Laboratory No. 27138, to determine the amount of gas given off while the coal was being ground and subsequently in vacuo, in an apparatus devised by A. C. Fieldner, Chemist of the Bureau of Mines. The method, it later appeared, was first used by a Frenchman, Henri Ghysen, in 1902, but apparently without results of importance.

For comparison, a sample of coal from the Pittsburgh, Pa., experimental mine was similarly treated, and likewise at a later date several samples from Nanaimo mines, British Columbia. The latter samples had been sent by the Chief Inspector of Mines, Mr. Graham, in conjunction with samples of coal and dust for explosibility testing at the experimental mine. The method used by Mr. Fieldner is as follows:—

Immediately after opening the sealed glass fruit-jar, in which each separate small sample was taken and sealed at the face of the mine and then shipped to Pittsburgh, the large lumps were quickly broken to pass through a ½-inch screen. All that passed through a ¼-inch screen was rejected; 125 grammes of the ¼- to ½-inch coal was at once placed in a gas-tight steel ball-mill (constructed in the Bureau's instrument-shop) containing flint pebbles, and the mill was rapidly evacuated to 3 mm., mercury pressure. The air and gas evolved by the coal during the evacuation was collected, measured, and analysed. Inasmuch as only a few cubic centimetres of gas were removed from the coarse coal during evacuation, it was assumed that practically no occluded gas would be lost during the preliminary operations.

The evacuated mill was rotated two hours, which by a preliminary test was shown sufficient to permit 90 per cent. of the coal to pass through a 200-mesh screen. (Apparently the fine grinding is the important factor in getting results so different than found by previous laboratory investigations.) The mill was then connected to a mercury-pump and evacuated; the gas collected over water, measured, and analysed.

The samples were ground "as received" from the mine and not air-dried. Several of the samples were ground submerged in water, in order to prevent the effect of heat from grinding, as it had been suggested that ethane and propane might have been produced through such heating. This, however, did not prove to be the case. The results are given in the following table:—

Occluded Gases in Coal.

Sample No.	16	Pgh. coal
Laboratory No.	27138	...
Weight coal (grammes)	125	125
Quantity and analysis of gas pumped out of ball-mill before and after grinding—		
Before grinding—		
Total volume gas c.c.*	1,493	1,517
Analysis per cent.—		
CH_4	0.36	0.08
C_2H_6	...	...
CO_2	0.40	0.13
O_2	20.75	20.76
N_2	78.49	79.03
After grinding—		
Total volume of gas c.c.*	263.0	65.6
Analysis per cent.—		
CH_4	15.3	10.2
C_2H_6	59.8	4.7
CO_2	2.8	12.0
O_2	2.1	2.6
N_2	20.0	70.5

* At 0° C. and 760 mm. pressure.

Total occluded gases in c.c. per 100 grammes coal*—

CH_4	37.6	6.6
C_2H_6	126.0	2.5
C_3H_8	...	...
CO_2	11.9	8.3
N_2	24.4	31.5
Total c.c.	199.9	48.9

It will be noted that 100 grammes of the British Columbia coal gave off 163.6 c.c. of methane plus ethane, and 100 grammes of Pittsburgh coal gave off 9.1 c.c. of methane plus ethane. Also in the former coal ethane was the predominating combustible gas. No CO or hydrogen was obtained from either coal. Mr. Fieldner comments that it is unfortunate that the containers leaked in transit. Had they been absolutely gas-tight it is certain that much more gas would have been obtained prior to grinding.

It appears that on evacuating the containers ethane is removed from the coal in addition to methane. No ethane was found in the gas surrounding the coal in the glass container. Neither has ethane been found thus far in the blower-gas samples from these or other mines investigated by the United States Bureau of Mines. It was suggested that possibly the ethane resulted from a heating effect during grinding of the coal in the ball-mill. Therefore, Mr. Fieldner had the experiment repeated, but grinding the coal while wet; i.e., the coal was actually covered with water in the mill while being ground. Ethane was again obtained in much the same ratio as before. Hence there is no reason to suspect decomposition by heat. Other investigators have found ethane in the gases pumped out of coal, although not in such large proportions.

Mr. Fieldner suggests valuable information might be obtained by employing some special gas-tight containers into which the fresh British Columbia coal could be put after screening at the face of the mine. The sealed container should be so designed that on arriving at the laboratory it could be connected directly to a vacuum-pump, the gases removed, and then placed in a suitable machine for rotating it so as to pulverize the coal in vacuo, and again remove and measure the gas.

Analyses were made by F. M. Seiber[*] of gases found in glass fruit-jars containing samples of fresh coal taken by Mr. Michell, of the inspection service of British Columbia, at various working-faces of Coal Creek Colliery, British Columbia, December 7th to 13th, 1916, and sealed immediately. Analyses were made after arrival of samples at Pittsburgh, January 4th to 8th, inclusive.

COMPOSITION OF GAS IN COAL SAMPLE CONTAINERS.

Sample No.	Lab. No.	Weight of Coal.	Total Volume of Gas.	Total Volume of CH_4.	Percentage of Composition of Gas.				C.C. CH_4 per Gram. of Coal.
					CH_4.	CO_2.	O_2.	N_2.	
		Grammes.	C.C.	C.C.					
17	27159	737	286	184	64.1	1.4	1.0	33.5	0.25
18	27160	788	366	90	24.6	0.9	4.4	70.1	0.11
19	27161	905	301	81	27.0	1.2	3.2	68.6	0.09
20	27162	827	338	53	15.8	0.4	1.2	82.6	0.06
21	27163	...	264	..	0.3	1.6	20.0	78.1	....

It was evident that all the containers permitted escape of gas in transit, as in all cases the contents of the cans were at atmospheric pressure. It will be noted the above gases contained no ethane.

OCCLUDED GASES IN NANAIMO COAL.

Subsequent to testing the Coal Creek and Pittsburgh coal in vacuo, samples were obtained from the Nanaimo mines of Vancouver Island, B.C., which had also been sent for explosibility

* Corrected for air leaking into ball-mill during grinding as indicated by the oxygen percentage.

testing. Incident to that inquiry, tests were made of the gases given off by the coals, using the method of fine grinding in vacuo. The results are given in the following table, including for comparison those of the Coal Creek and Pittsburgh coal previously reported in detail.

Occluded Gases in Coal from Pittsburgh, Pa.; Coal Creek, B.C.; and Nanaimo, B.C., at 760 MM. and 0° C.

Mine.	Sample.	C.C. per 100 Grammes of Coal.							
		Total.	N.	CO_2.	CH_4.	C_2H_6.	C_3H_8.	Total Paraffins, Hydrocarbons.	
								C.C.	Vols.
Pittsburgh, Pa......	..	48.9	31.5	8.3	6.6	2.5	....	9.1	0.12
Coal Creek, No. 3.....	16	199.9	24.4	11.9	37.6	126.0	....	163.6	2.12
Nanaimo coals—									
No. 1, Western Fuel	10	139.0	51.3	3.1	62.7	21.9	....	84.6	1.10
No. 1, "	11	169.4	9.0	2.0	128.6	29.8	....	158.4	2.05
Reserve mine *.......	1	46.9	43.1	1.3	....	1.0	1.5	2.5	0.03
"	2	69.6	40.5	2.9	....	20.5	5.7	26.2	0.34
" †.......	2	28.7	14.2	0.2	....	10.7	3.6	14.3	0.19
" ‡.	2	16.7	14.1	0.3	2.0	0.3	....	2.3	0.03
" †.	3	48.2	13.5	0.1	21.0	13.6	....	34.6	0.45
" †.......	4	24.0	14.8	0.3	....	1.8	7.1	8.9	0.11
"	4	....	....	0.5	....	6.0	3.6	9.6	0.12
"	5	37.9	20.1	0.9	....	5.0	11.9	16.9	0.22

* Result approximate as to absolute quantity, as a little gas was lost in making the measurement.
† Ground in vacuo but under water, grinding not so fine as when dry.
‡ Not ground fine.
‖ Ground in atmosphere of nitrogen; hence nitrogen given off by coal could not be determined.

No carbon monoxide nor hydrogen in any sample. Samples 2 and 4 ground in atmosphere of hydrogen, which was absorbed to greater volume than the other gases evolved; in the case of 5 the contraction was 51.3 c.c.

Analyses of Blower-gas Samples from Coal Creek Mines.

Following are the analyses of gas from blowers issuing from special boreholes in the rib-side of headings in the Coal Creek mines analysed (*a*) by the Canadian Department of Mines, and (*b*) by the United States Bureau of Mines:—

Location in Mine.	CO_2.	O_2.	CH_4.	N.	Air.	Excess N.
1. No. 1 East mine, No. 1 borehole, 18 room, 10 East (*a*).....	0.07	13.3	30.7*	55.3	63.5	5.3
Bottle broken in transit (*b*).						
2. No. 1 East mine, No. 1. borehole, 22 room, 10 East (*a*).....	0.07	14.7	22.8†	61.8	70.2	7.0
" " " (*b*).....	0.10	20.69	0.14	79.07	....	....
3. No. 1 East mine, No. 3 borehole, Counter main level (*a*)....	0.8	17.7	10.7‡	70.8	84.5	4.8
" " " (*b*)....	0.89	18.27	11.64	69.20	....	0.5

Notes by Analyst, Canadian Department of Mines:—
* No ethane present. Presence of hydrogen in small quantities seems evident.
† No ethane or hydrogen detected in sample.
‡ Probably trace of hydrogen.

It will be observed that analyses of duplicate samples 2 (*a*) and 2 (*b*) disagree badly. It is conjectured that the wax stopping of one or both of these samples and 3 (*a*) and 3 (*b*) failed in transit.

Review of Gas Analyses.

Regarding the analyses of gases from the boreholes as the samples were gathered from special boreholes drilled to obtain pressures as hereinafter described (page 19), these boreholes being cased with pipe set in cement, it is improbable that air could have leaked into the holes from which the gas issued with some pressure. The gas was collected in evacuated tubes, the tube-opening being held in the mouth of the casing. Either air entered at the point of collection, in spite of the care exercised by George O'Brien and D. Michell, or the wax stopper permitted entrance of air in transit. Nevertheless, it will be observed that there was from 5 to 7 per cent. of nitrogen in excess of that of normal air; hence it is probable that nitrogen is a constituent of the gases given off by the strata.

It will be observed that the analyses of the blower-gas report no ethane content, although the analyst mentions indications of hydrogen. In previous analytical work on the many mine-air and gas samples collected by the Inspectors of British Columbia in the Crowsnest mines, no hydrocarbon gas other than methane has been reported.*

The contrast with results from fine grinding are most striking; the amount of hydrocarbon gases reported by Mr. Fieldner figured to volumes of gas to volume of coal (assuming for approximate figures a specific gravity of coal of 1.3) is shown in the tables on pages 12, 13, 14.

Investigators in the past have either not crushed the coal to a finely divided state, or have only ground it to pass through 10 or at most 30 mesh. Whereas, in these tests, Mr. Fieldner ground the coal to pass through a 200-mesh sieve. He comments that it is evident that ethane and higher hydrocarbons are not given off by the coal as readily as methane. For instance, a sample of Nanaimo coal, ¼ to ½ inch in size, sealed in a vacuum bulb for ten days, gave off much more methane than ethane, while another sample of the same coal gave off, on grinding to 200 mesh, more ethane and propane than methane.

The wide diversity of volumes given off by different coals is surprising, and this diversity occurs in the same mine as shown by samples from the Reserve mine. To some extent the latter may be due to the method of sampling in the mine and the preliminary treatment and variation in grinding. It is noticeable, in comparing results of samples from the same mine, that the ratios of the different gases is of the same order. Unfortunately, the method was not developed in time to try out the various samples of coal from the Coal Creek mine; one sample, No. 16, from Coal Creek No. 3 mine was tried, and the results caused surprise, especially after testing similarly a sample from the experimental mine. This proved to give off very little gas. As regards the latter sample, the experimental-mine workings are so near the outcrop and under such shallow cover that different results might be obtained than with a sample from the Pittsburgh bed in a deeper mine. Nevertheless, the dust from the experiment-mine coal proved to be more sensitive to the propagation of an explosion than the Coal Creek and Nanaimo dusts.

The diversity in results and the unusual amounts of hydrocarbon gases given off by the Coal Creek coal points to the advisability of continuance of these laboratory investigations on samples gathered systematically from all the Crowsnest mines and other typical mines in British Columbia. It is probable that investigations of a similar nature will be made by the Bureau of Mines on coals from various parts of the United States as opportunity presents.

In the Crowsnest collieries the question of whether ethane is given off under special conditions should be studied. In gas analyses by the ordinary combustion method ethane in small quantities is not detected, and, as usually the samples of mine-air collected contain only a few per cent. of gas, ethane would go undetected, being classed as methane. Hence, not finding it hitherto should not be considered as positive evidence of its not being given off. Under the great pressure of the heavy covering, the Crowsnest coal in the process of mining is subjected to a squeezing action, which tends to crush and grind the particles of coal one against the other. This may produce a condition which laboratory grinding would be analogous to. How occluded or contained gas is held in the coal substance is an unsettled question; that is to say, is the coal substance so impervious that the gas is held in minute pores like little bottles, only to be released when these are broken, or is it held by chemical bonds, so unstable that on a slight relief of pressure the gas is given off? It is stated by physicists that external pressure which obtains even with coals at great depth is insufficient at normal temperatures to liquefy the gases.

On the other hand, the surface tension of the coal-particles is very great, and some physicists have contended that films of the gas are held on the surface of the particles of coal under such tension that the gas is in compressed state equivalent to liquefaction. If so, when the coal-bed is opened, the coal near the headings and rooms may begin to release its contained gas. In the

* It is claimed that "in 1910 Professor John Cadman found ethane in the air of the Bellevue mines of Alberta." Page 723, Transactions of the Institution of Mining Engineers (Great Britain), Vol. LI. Ethane and other hydrocarbon gases except methane have never been found in the mine-air in mines of the United States unless by leakage from deep natural-gas wells.

Crowsnest mines large volumes of gas are given off at the faces. Such gas may have been stored in the crevices and open joints, and also in part may be occluded gas.

Normally, coal of the Cretaceous, which is the geologic age of the Crowsnest beds, is "sub-bituminous" coal, which is sometimes called black lignite. But Crowsnest coals have been advanced to the bituminous and semi-bituminous stage by heat and pressure in the Rocky Mountain uplifting, expelling from the coal substance moisture and gas. The latter, when it is held in by impervious or nearly impervious covering, collects in or saturates the coal-beds and enclosing strata.

The amount of gas given off by the freshly broken coal in the mines of the Crowsnest coalfield is very great, far greater than in most coals. It was observed in certain gaseous parts of the Coal Creek mines that, if a safety-lamp was set in a depression in a freshly broken-down pile of coal, the gas from the coal would flame in the lamp and extinguish the light. On the other hand, as will be shown later, even if two volumes of gas are given off per unit of coal volume, the amount is not nearly sufficient to account for the gas carried out by the return air-currents in the Crowsnest coal-mines.

As already indicated, methane and possibly ethane is given off in coal-mines in two ways:—

First, from the volume stored at high pressure in the crevices, slips, and joint-planes of the coal and adjacent strata, also from the cavities, if any exist.

Second, to a less extent from the coal broken down by mining operations, which gives off more or less slowly gases stored in its pores. The Crowsnest coal-mines have the unenviable position of being among the most gaseous mines in the world, according to the figures obtained through mine-air sampling by the British Columbia Mining Department. These figures are obtained from Thomas Graham's paper on "Some Gaseous Mines in the Crow's Nest Pass Coal Field" (referred to previously), and also from later records of the Department.

Gas-flow, Michel Colliery.—The records show that from Michel No. 3 East mine there is discharged in the ventilating-current on working-days from 1,104 to 1,524 cubic feet per minute of pure methane (at atmospheric pressure), which for twenty-four hours makes a total of from 1,590,000 to 2,195,000 cubic feet. On the basis of the coal mined (average per day for the period), 500 to 550 tons respectively, there was discharged 3,179 and 3,990 cubic feet of pure methane per ton of coal produced.

It is noticeable that on idle days the flow decreases; for example, on September 26th, 1916, this mine had lain idle since August 7th, when an explosion had occurred, and the flow of pure methane was 929 cubic feet per minute, or a total of 1,337,760 cubic feet per twenty-four hours. The question arises, is the decrease of flow due to the headings and rooms not penetrating into new areas, or is it due to fresh coal not being broken in daily work?

As the Pittsburgh laboratory tests indicate that even in vacuo but 2.1 volumes of methane plus ethane are given off on fine grinding, this figure may be considered an extreme one. Five hundred and fifty tons, a day's output at that time of the mine, occupies about 13,750 cubic feet in-place, and if it gives off 2.1 volumes of hydrocarbon gases, the total of the gases for twenty-four hours would be 28,875 cubic feet, or but 1.3 per cent. by volume of the gas given off on an idle day. On the other hand, the flow on an idle day after standing fifty days was 60 per cent. of the maximum outflow of a working-day. Similar results, differing slightly in proportions, are found in other Crowsnest mines. Accordingly, one is forced to conclude that the larger part of the gas entering the mines comes from that stored in crevices, slips, joints, and bedding-planes; second, a considerable part comes from exposure of fresh coal-faces and fresh roof areas; and, third, a small amount from the breaking-up of the pieces of coal in mining operations. In any case, it would appear that headings driven well in advance serve a valuable purpose in drawing off stored gases.

In the Michel Old No. 3 mine the methane-flow per minute ranged in the period from April, 1915, to October 24th, 1916, from 124 cubic feet on an idle day to 1,574 cubic feet on a day of active production of coal and correspondingly of uncovering of new faces.

This mine appears to be more gaseous per ton of coal produced, the figures ranging from 5,000 to 8,000 cubic feet per ton of production, but it is believed that this method of comparison is misleading. It is probable the territory mined is more gaseous.

The weight of the gas itself removed or flowing from the strata is worthy of attention. In the two mines just referred to, which are adjacent, the average weight in tons of pure methane carried out daily by the ventilating-current was 71 tons (of 2,000 lb.), which for a whole year

"A." Showing Steep Dips at Western Escarpment in Upper Background. View looking North-west.

"B." Showing Shoulder of North Mountain-side which is cracked away 1,200 feet vertically above No. 9 Mine, Coal Creek.

"C." Looking North across Coal Creek Valley.

"D." Looking East up Coal Creek towards Plateau.

"E." Looking West down Coal Creek.

would amount to 26,000 tons. When it is considered what a great pressure the coal-beds are subjected to, and the fact that they are so much fissured as to be very weak when unconfined, it is a question if the loss of gaseous material may not cause some actual subsidence of the strata in the immediate vicinity of the mines of small vertical dimension, but nevertheless it may be a slight factor in a local subsidence over and adjacent to the mine-workings.

The Michel mine on the North side has shallow cover, and hence the amount of methane given off is relatively small—20 to 40 cubic feet per minute.

Gas-flow from Coal Creek Collieries.—The Coal Creek mines working on the South side of the creek are more extensive than the Michel mines. In No. 1 East mine, on February 23rd, 1916, when the mine was idle, there was 1,247 cubic feet per minute of methane given off; and on April 14th, 1916, when the mine was working, 2,906 cubic feet was discharged. This quantity represents the maximum discharge from any of the mines according to the records secured. At this rate there was thrown out of the mine in twenty-four hours, 4,184,000 cubic feet of methane, which would weigh 78 tons (of 2,000 lb.). On the basis of the cubic feet of methane per ton of coal mined, the figures 2,789 cubic feet give a much smaller ratio than that found at the Michel mines. The production of coal was then about 1,500 tons. Evidently from this the greater part of the flow comes from the coal stratum rather than liberated from the breaking-down of the coal in mining.

In the other mine working in No. 1 bed on the South side of Coal Creek, No. 1 South, the discharge of methane per minute in the "main return" ranged from 218 cubic feet per minute on an idle day to 459 cubic feet on a working-day.

The No. 2 bed lies below the No. 1 bed from 20 to 40 feet in the western part worked by No. 2 mine, under No. 1 South, but the interval between the beds increases to 150 feet where No. 3 mine works under No. 1 East.

The No. 2 mine main return also carries the gas-drainage from the abandoned part of No. 2, in which the "bump" area was located. The main return of No. 2 carried on an idle day 140 cubic feet of methane and on a working-day 250 cubic feet. The No. 3 mine main return carried on an idle day 381 cubic feet of methane and on a working-day 947 cubic feet.

The records of the methane given off by the respective beds may be summarized as follows, representing the minimum discharge recorded for an idle day and the maximum recorded for a working-day:—

No. 1 Bed (Upper).	Idle Day, Minimum recorded, Cu. Ft. per Minute.	Working-day, Maximum recorded, Cu. Ft. per Minute.	Tonnage of Coal produced, Average per Day.	Acreage covered by Mine.
No. 1 East	1,869	2,906	1,500	198.0
No. 1 South	218	459	400	....
Totals	2,087	3,365	1,900	....
No. 2 Bed (Lower).				
No. 3 mine	381	947	250.	....
No. 2 mine	140	250	300	....
Totals	521	1,197	550	402.7
Grand totals	2,608	4,562	2,450	....

On the basis of the total methane discharged, the upper bed appears to be more gaseous than the lower bed; but in view of the fact that over three times as much volume of coal is taken out from the upper bed as from the lower, it is probable there is not much difference in the amount of total free gas in a unit of area in the respective beds.

Gas Conditions in Hosmer Colliery.—The Hosmer mines, situated on the west escarpment about six miles north of Coal Creek in an air-line, were closed and these mines were not visited.

According to the Government report of 1912, entitled "Investigation of Coals of Canada," thirteen seams were being opened at Hosmer from 4 to 30 feet in thickness. The opening tunnel, 900 feet long, had cut ten seams, five of which were being developed and which had a total working thickness of 40 feet, the sections being given as follows:—

No. 2 seam, 10 feet.
„ 6 „ 6 „
„ 9 „ 5 „
„ 10 „ 20 „

The seams varied from a dip of 65 degrees to 25 degrees. The tunnels started in the Fernie shales underlying the coal-measures, reaching the latter at a distance in of 850 feet and terminating in a hard conglomerate overlying the coal-measures, and therefore the seams cut included the whole series. It appears that very troubled or faulted areas were encountered which led to the shutting-up of the new mine a few years ago. The colliery is said to have been gaseous, but outbursts were not reported.

Outbursts of Gas in Carbonado Colliery.—The Carbonado mines were opened by the Crow's Nest Pass Coal Company in 1901-2 on the western escarpment of the plateau at a point on Morrissey creek about seven miles in an air-line south of Coal Creek. According to W. F. Robertson, on the "Rocky Mountain Coal Field," published in the Annual Report of the Minister of Mines for 1909, entries driven in on the strata of the beds show these thicknesses:—

No. 1, 12 feet.
„ 2, 30 „
„ 3, 4½ „
„ 4, 16 „
„ 5, 18 „

He states that the other beds were known to be above and below these, but not developed. The coal was found to be very friable, and on account of the high percentage of fixed carbon it would not coke properly in bee-hive ovens and was too small in size for locomotive use. In 1903 there were great outbursts of gas, causing loss of life, so that the mines were closed, but were reopened in 1907; but as the gas-outbursts continued to occur the colliery was again shut down in 1909. The locality was not readily accessible on account of snow and a visit was not attempted.

In 1903, when the main entries of No. 1 mine had been driven 2,000 feet from the outcrop, a great outburst of gas occurred, in which 1,456 tons of coal was blown out of the face of the main entry, making a tunnel cavity 110 feet beyond the original face. Other lesser outbursts occurred, and in 1904 there was another great outburst in which fourteen men were killed, the coal thrown out filling the level for 400 feet according to Inspectors Dick and Morgan. The mine foreman "reported everything clear and quiet at face twenty minutes before the outburst."

Thomas Graham states: "The displacement of coal in this outburst was estimated by the management as 3,500 tons. The volume of gas given off in the first thirty minutes after the outburst was estimated by various authorities at from 2,000,000 to 5,000,000 cubic feet."

Outbursts of Gas in other Mines of the Crowsnest Field.—No such great instantaneous outbursts have occurred in mines other than the Carbonado mines, but lesser, slower outbursts have taken place in the Coal Creek mines. In the No. 2 South, 900 feet inby the main parting near a faulty and crushed zone, an outburst took place several years ago, which pushed in 750 tons of coal. It gave premonitory symptoms, so no one was lost, but for two days no one could enter the place on account of the gas and broken coal. Similar but smaller "rushes" of gas and coal have occurred in the Coal Creek mines, and frequently miners are driven from the face of the workings, as occurred during the visits of the author, by the gas and breaking coal-face.

In some virgin areas, when the entry is advancing by employment of three shifts, it has been found necessary to slow the advance on account of gas given off, by cutting out one or two of the shifts.

When the "bumps" occurred in Coal Creek No. 2 mine in 1907-8 they were accompanied by strong inflows of methane which smothered the men entrapped by the uplifting of the "bottom" or floor. Hence it was believed by some that gas-pressure might have been responsible for the "bumps." But this view had to be abandoned when the great bumps in the No. 1 East mine occurred last November, as no gas was given off when these occurred.

OUTBURSTS OF GAS OF VARIOUS KINDS.

Gases of different kinds are found in the earth's crust in many places, collected in porous strata, and in denser strata in cavities and rock joint planes when confined by impervious strata above. The most common gases thus confined are: "Natural gas" (hydrocarbon gas), which is usually associated or in contiguous territory with petroleum, and is found in various sedimentary beds generally adjacent to thick shale-beds; "methane" (CH_4), commonly found in coal-measures; carbon dioxide (CO_2); and nitrogen, sometimes found adjacent to deeply buried limestone and occasionally in shattered eruptive rocks, as at Cripple Creek, Colorado.

Great outbursts of carbon dioxide have occurred in the coal-mines in certain small coal-basins of Central France adjacent to ancient crystalline rocks, throwing out thousands of tons of coal and causing loss of life, but outbursts of this gas (CO_2) are not known in the principal coalfields of the world.

Inbursts of natural gas into mines have occurred in Pennsylvania, West Virginia, and Illinois mines, where the measures containing such gas have underlain the coal-measures; but, although the gas-pressures are sometimes above 1,000 lb. per square inch, violent outbursts have not been reported since the distances between the gas-measures and coal-measures have been too great.

OUTBURSTS OF METHANE.

Methane-outbursts into coal-mines have not been uncommon in many coalfields besides the Crowsnest field. Such outbursts have occurred only when the coal-bed being mined is deeply covered to a depth of over 1,000 feet or more by strata containing impervious shales. Methane found in coal-measures is generally believed to have been derived from partial distillation of the bituminous matter in the coal-seams and bituminous shales, in the natural process of coal formation by chemical reactions aided by heat and pressure from deep burying and mountain upbuilding.

It is therefore believed that all coal-beds have produced large amounts of hydrocarbon gases, but where the beds are thinly covered or are covered only by pervious rocks like sandstone, or the cover is much broken by fault-planes extending to the surface, the gas has escaped. Generally, the more deeply buried the coal-beds, the farther advanced from the lignitic stage; the larger the volumes of the residual gas, methane, contained in the strata, and also the greater the pressure under which the gases are confined. In Great Britain, in deep boreholes from the surface to the coal-beds, the pressure of gas attained 500 lb. and at Belgian mines 657 lb. per square inch. (*See* United States Bureau of Mines Bulletin 72.) Nevertheless, it is commented by Belgian investigators that the highest pressures are not found in the coal areas subject to outbursts, but rather in the denser coals.

Great outbursts of methane (chiefly) have occurred in the deep Belgian mines, in one of which many years ago the ventilating-current was reversed and about 140 men smothered, the gas taking fire at the surface and burning for a day or two. Several hundred other outbursts have occurred in Belgian mines, causing many deaths of miners. Such outbursts have been accompanied by the dislodgment of quantities of coal blown out in large part as dust. It has been found that these outbursts occur in crumpled zones and at buried anticlines.

Outbursts of methane of lesser magnitude have occurred in the coal-mines of other European countries than Belgium—i.e., in Great Britain, especially in Yorkshire collieries and Scotch mines—causing fatalities. Small outbursts have also occurred in coal mines of the United States, in the anthracite district of Pennsylvania and in Colorado.

The great outbursts of methane that occurred in the years 1903 and 1904 in the Morrissey mines in the Crowsnest coalfield, and on reopening the mines in 1909, when the mines were again closed, have been unparalleled except by the Belgian outbursts.

PRESSURE OF GAS IN COAL CREEK MINES.

On account of the apparent great force indicated by the outbursts at the mines at Morrissey and the pushing-out of the coal-faces at times in the Coal Creek mines, it was believed that the gas-pressure in the coal-bed must be very high. To determine what the pressures were, three sets of boreholes, three holes 10 to 14 feet apart in each set, were drilled into the solid coal of advance places near the face on the lower rib. The holes in each case were 8, 16, and 24 feet deep respectively. Three-eighth-inch pipes were set in each hole and allowed to project about ½ foot from the hole. The inner 1, 2, and 3 feet of each pipe respectively for the 8-, 16-, and 24-foot holes were perforated, and outby this each had a collar; burlap dipped in cement grouting was forced back against each collar to serve as stemming material; then cement and sand grouting was poured into each hole, the holes being pitched downward 1 in 24, until the grouting nearly filled the hole; then cement mortar was used to finish filling. After the cement had set a pressure-gauge and a valve was screwed on to the end of the pipe.

In all cases gas blew freely out of the pipe, but the pressures obtained on shutting the valves were surprisingly low. When each valve was shut about a day after beginning the respective hole, the maximum pressure was quickly obtained, and thereafter there was practically no change. The maximum pressures and the temperatures of the mine-air and in the bottom of the boreholes were read by Mr. Michell, and are summarized in the following table:—

	Borehole Depths.			Temperature Fahr.	
	8 Ft.	16 Ft.	24 Ft.	Bottom 24' Hole.	Mine-air.
	Lb.	Lb.	Lb.	Degrees.	Degrees.
No. 1 East mine					
18 room, 10 East entry (in solid coal on lower rib).........	3	0.5	13.5	46	40
22 room, 10 East entry (in solid coal on lower rib).	0.5	7	18	50	48
No. 3 mine—					
Counter to Main level (in solid coal on lower rib).........	1.5	2	2	65	60

It is difficult to account for the erratic showing, but owing to the great friability of the coals it seems probable that there is a rapid escape of gas as the mine-face advances. With such conflicting results it would not be wise to draw conclusions from the above tests. It would seem advisable to drill and case some holes considerably deeper, say 100 feet in advance, and thus obtain records of the fall of pressure with the advance of the face, which would permit curves of this fall to be drawn, and in this way help determine how a given area of coal-bed may be drained of gas with lessened danger to the men.

One method of protecting men from outbursts is to keep boreholes in advance. This is the method practised in many mining districts of the world, but hitherto it has been argued that it would not permit the advance discovery of a stored pocket of gas such as was encountered by the Carbonado mines. The author of this paper is not convinced by these arguments, but it is his judgment that if a sufficient number of boreholes be drilled, spreading fan-shaped from the main advance entries, these would approach near enough to such a pocket of gas and crushed coal to show by the gas-flow from the pipe that there was a dangerous area ahead, and until it had been drained by other boreholes the entry or room driving should cease.

Temperature in Boreholes.

The temperature in the bottoms of the 24-foot boreholes is also most surprising. Apparently the only way that the low temperatures in the boreholes in No. 1 East mine can be accounted for is by the assumption that it was from the expansion of the stored gases as they are released at or near the face. This matter also needs further investigation in connection with drilling deeper boreholes and obtaining the readings when the casings were capped, so expansion does not take place into the borehole lining.

Question of Gas-flow and Outbursts.

The matter of gas-flows and outbursts, while not so immediately acute in the operation of the Coal Creek mines as that of "bumps," yet is a most serious and, in fact, vital consideration in planning for future operations in these and other mines of the Crowsnest coalfield. Even in the question of lessening the danger of "bumps," the number of airways that must be maintained to meet the gas-flows affects the system of mining which may be adopted.

Mining Conditions and Methods in the Coal Creek Mines in Relation to the "Bumps."

The No. 2 seam at Coal Creek was opened first and mined extensively by the Old No. 2 mine and No. 3 on the South side of the creek. The coal varied in thickness from 4½ feet on the dip or East side of No. 3 mine to 11 feet as taken out on the West side of No. 2 South. On the West side there is a crumpled zone in which the coal in places is 20 feet or more thick, but crushed and dirty. Through the area in the inner central portion of No. 2 mine, later affected by "bumps," and now closed off, the coal is said to have been 4½ to 5 feet thick.

The general method of mining in the Nos. 2 and 3 mines was by the pillar-and-stall system, the "stalls" or "rooms" being driven off wat r-levels which branch from inclines. The entries were 12 feet wide and the rooms from 16 to 20 feet wide and about 40 feet apart, the pillars thus being 40 feet wide and about 60 feet long between crosscuts. The workings and the pillars were very irregular.

In some places long-wall was started in irregular panels; in other places the pillars were withdrawn. In the "bump" area, as indicated in the attached blue-print, 50 to 60 per cent. of the coal had been mined out; this correspondingly increased the load on the pillars, which bore the weight of 2,000 feet of cover.

The roof of No. 2 mine is a fairly strong shale, but the floor is a softer shale.

I will not attempt to describe individual "bumps," which first became serious in 1906. On the mine-map, Exhibit 5, where there are eight circles enclosing letters from A to H, fatalities occurred, as the result of "bumps" in the immediate vicinity. The last, on July 31st, 1908, was the most serious. Mr. Robertson reported that "twenty-four men were cut off and all would have been suffocated had it not been for a supply of fresh air supplied by a break in the compressed-air pipes, enabling twenty men to be saved."

Mr. Robertson further states in his Annual Report for the year 1908 that:—

"A reference to this plan (of the No. 2 mine) will show that the area of disturbance in which all these 'bumps' have occurred is between the main entry and the High Line entry and immediately surrounding and including the area from which the pillars have been extracted, an area of about 1,500 by 1,000 feet, and this area stretches across from one entry to the other. These facts would indicate that the sagging of the roof over the area from which the pillars had been extracted caused an undue pressure on the immediately surrounding pillars, which, transmitted to the pavement, apparently caused it to burst upwards with the liberation of gas and accompanying shock. There was apparently no serious caving of overlying measures that might fill up the space and relieve the pressure. The area of pillar-extraction—some 30 to 35 acres—is located in the centre of the mine-workings and under an overburden of 2,000 feet. In this present case the disturbances have, so far at least, been localized; whether they will spread to the rest of the workings time only will show.

"I think that there will be no sudden outburst, provided no further attempts are made to extract pillars from a central area which has stood for some time. If the extraction of pillars had been commenced within a reasonable time and from the outcrop, the roof might probably have subsided behind such workings quietly and no serious disturbances have taken place."

Mr. Robertson's prediction relative to there being no further sudden "outburst" or "bump" in No. 2 mine proved to be correct. In accordance with his recommendations, the operating company was "prohibited from continuing any of the present workings of that part of No. 2 mine lying between the main entry and the High Line entry inside of No. 1 West level main entry, and No. 1 East level, High Line, or of extracting pillars within this area in this mine, such prohibition to include the main entry and parallels inside of No. 1 West level."

As regards Mr. Robertson's opinion "that if the extraction of the ..llars had commenced at the outcrop the roof might probably have subsided behind such workings quietly" seems to be supported by what happened on the north side of Coal Cre...

After the No. 1 bed had been mined by No. 1 Nor... many pillars extracted and some long-wall operations conducted near the outcrop, this ... owed by working the No. 2 seam by opening No. 9 mine under the No. 1, with similar ext... n by pillar-drawing and long-wall; although the workings were irregular and unsystematic, the fact that extraction began near the outcrop caused a shoulder of the mountain, to a height of 1,200 feet, to quietly subside at the outcrop, the mass hinging on the solid unmined area, cracks opening across the projecting shoulder 1,200 feet above. So little disturbance did this make that it was not real...ed what had happened until the cracks were noted. (*See* Exhibit, Photo "B" of "shoulder" over Mines No. 1 North and No. 9.)

MINING DEVELOPMENTS AFTER "BUMPS" OF 1908.

Following the shutting-up of the "bump" area in No. 2 South mine, the work in this seam was continued only in the east and west portions, called No. 3 mine and New No. 2 mine. In these developments large pillars were left between each pair of rooms 150 feet wide, and between the two rooms of a pair a 50-foot pillar was left. The No. 1 seam, 9 to 12 feet thick, lying above the No. 2, was then developed over the west part of Old No. 2 mine by what is termed the "No. 1 South mine," and subsequently by the opening of No. 1 East mine, immediately over the central part of No. 2 mine.

DESCRIPTION OF NO. 1 EAST MINE.

The No. 1 East mine was the only mine systematically planned of the Coal Creek mines, and the advance plan was rigidly adhered to. The main entries run due south, which is approximately on the strike of the bed; the cross-entries, 10 feet wide, which on the west side are driven "to the rise" and on the east side "to the dip," are 600 feet apart, and in the inner part of the mine 1,000 feet apart; each one of the pair is 60 feet apart. Rooms only 14 feet wide are parallel with the main entry and are also in pairs. The two rooms are 60 feet apart and the pairs 150 feet apart. Crosscuts are between each of the two rooms, but the pairs are only connected when necessary for special reasons, so that ordinarily over the "bump" area between each pair of rooms there is a pillar 150 x 600 feet. Only 25 per cent. of the coal was taken out by this advance work, and no pillars were to be pulled until the mine was retreating as a whole. (*See* Exhibit 4, map of mine.)

The coal is from 10 to 12 feet thick, to a slickensided rash 2 to 3 feet thick, which had no strength and was kept up by lagging and close timbering to prevent mixing with the coal in loading. The cross-timbering under the mine regulations does not have to be closer than 1 yard apart, but the miners who were paid $1 per set, usually preferred to place two sets to a yard. Above the rash is 2 to 3 feet of coal, usually of excellent quality; this is not obtained in this advancing work. Over the coal there is a strong sandy shale approaching a sandstone in places. Fifty feet above the coal-seam there is said to be a strong conglomerate 15 to 20 feet thick. There are also other beds of conglomerate higher in the section. Owing to the deep snow on the mountain-sides, the rock-exposures were not visible, except at the tops of the ridges.

The No. 1 East mine rapidly developed; the mining conditions were good, except the immediate top, consisting of the rash and soft coal, weighted heavily on the timbers, and after a time they had to be removed or else the false top allowed to fall, and timbering carried up to the main roof.

No explosives were used in mining, but the coal, assisted by the gas-pressure, worked off easily, and a miner could load 7 to 8 tons per day of "eight hours from bank to bank," which meant about seven hours at the face. The output of the mine attained 1,500 tons per day. The mine passed over the "bump" area of No. 2 mine, which is about 150 feet below it, without noticeable effect, and by November, 1916, the rooms to the east of the main entries were 300 to 400 feet beyond the (projected upward) edge of the abandoned No. 2 mine, and the main entries about 700 feet beyond the edge (projected upward) of the general line of faces of Old No. 2 mine, or about 5,000 feet from the entrance portal.

"BUMPS" IN NO. 1 EAST MINE, NOVEMBER, 1916.

November 7th, 1916, at 9.55 p.m., there was a "bump" affecting Nos. 8 and 9 rooms off the No. 14 East, resulting in a fall of loose rock which occurred in No. 8 room, hemming in a horse. A small fall occurred in No. 9 room, injuring a man. A party of ten men and two firebosses went to work in No. 8 room to clean up the falls to release the horse, but a more severe "bump" occurred at 1.55 a.m., causing two heavy falls in No. 8 room, burying and killing one man and hemming in eleven others. By 4 a.m. they had worked their way out through a crosscut into No. 7 room, thence out. At 5.25 a.m., November 8th, the third and heaviest "bump" occurred, which not only shook the inner part of the mine, but created earth-tremors which were felt for many miles, strongly at Fernie, and in many places a number of miles to the north and south.

Falls of false top were general inby the No. 14 East and West. Those in the main entry blocked the ventilating-current of 120,000 cubic feet per minute; the intaking air-column, being 4,000 feet in length, acted like a water-hammer; the pressure ran up, bursting the wood stop-plugs, and causing a reversal of the current in such strength that several men, one of them the general manager, Mr. Wilson, were hurled outby before it, sticks and stones being carried along.

There were many narrow escapes of those in the mine working to clean up the previous falls, but all escaped, though several were battered up. While hundreds of falls had occurred, practically all that could be observed were of the rash and top coal only. Apparently the main roof had stood the shocks.

A fourth but lesser "bump" occurred over the main entry on November 13th, causing the bottom to heave in the centre 2 feet, and for a distance of 200 feet opposite the No. 12 West and outby same for 120 feet. This was the only "bump" which caused the floor to lift. Since the fourth "bump" there have been roof knocks, rather than "bumps," at more or less frequent intervals, causing no damage. Neither the large nor the subsequent small "bumps" were accompanied by outbursts of gas, unlike the "bump" in No. 2 mine.

Mr. Graham, Chief Inspector of the Province, following the occurrence of the "bumps," decided to prohibit, pending investigation and further orders, work in a certain section inby the No. 10 East and West entries overlapping, but exceeding in area the prohibited district in Old No. 2 mine.

THEORY REGARDING "BUMPS."

As already implied, "bumps" are manifestations of pressure, and occur only when the mines are at great depth, usually exceeding 1,000 feet. If the measures overlying the mine are soft and pliable, such as shale-beds, "bumps" will not occur, although "mine squeezes" may take place. "Bumps" therefore occur only when there are massive and rigid beds above, such as sandstone, conglomerate, and limestone. Mine squeezes originate where the pressure thrown on the mine pillars is sufficient to crush them, or the immediately overlying roof or underlying floor is too weak to withstand the load put on it, through removal of part of the natural support by the excavations, but such squeezes will only result in "bumps," as stated above, when there are rigid rocks of great thickness above.

The cause of "bumps" is thought by the writer to be this: When an area in a coal-bed has been mined out or when a "squeeze" has occurred from the weight of the lower-lying roof, so that a subsidence or separation of the lower stratum from under the rigid rocks has occurred, then the massive rock will span the subsidence. If the diameter of this subsided area is limited —that is, let us say, 50 to 100 feet—a strong sandstone or limestone stratum would easily be self-supporting; but if the subsidence of the lower measures (though only a foot or two in vertical displacement) was 200, 300, or a 1,000 feet in diameter, so that the underside of the massive rock was not supported over this space, then it is probable that the lower layers of such a rock would not stand the strain, and a large disk-shaped piece would drop, 1, 2, or 3 feet, as the case might be, giving a blow of tremendous force which would produce the effect called a "bump," and the larger and heavier the slab the greater would be the "bump." Above such a great fallen slab there would in all probability be almost the same depth of space as was represented by the subsidence, and there would be a flat, dome-like arch, supported at the sides of the unsubsided area.

If the subsidence of the lower measures continued through enlargement of the area of mining or of "squeeze," there would probably be a great saucer-like mass of larger diameter than the previous great slab fall upon it, causing a second "bump." In time, further saucer-like masses would drop, increasing the height of the dome until it either reached the surface or reached a soft stratum which would bend. The foregoing assumes a massive stratum without joint-planes or fault-planes which would modify the character and size of the falling masses, each of which strike a great blow, and which is believed is the cause of the successive "bumps" in Coal Creek Nos. 1 and 2 mines.

In the foregoing it is assumed that the coal strata is not dipping at sufficient angle to cause slipping of the strata on the bedding-planes. Steeply dipping strata would necessarily act very differently in the movement of the mass which gives the blow. When the overlying strata is in the form of mountains with steep slopes and with great slips or fault-planes developed, the character of the rock-movements would be profoundly altered; but in any case it is believed that when thousands or hundreds of thousands or even millions of tons of rock fall only a few inches, a gigantic sledge-hammer blow is given to the mine-roof, setting up vibratory waves like the earth-tremors which are called earthquakes. The direct blow on the mine-roof may break timbers and throw down great amounts of soft roof material, cause slabbing of all the coal, or, where the coal is strong and the bottom of the floor weak, cause a sudden uplifting of the floor. The latter effect was the chief manifestation of the "bumps" which occurred in No. 2 mine from 1906 to 1908, whereas in the recent "bumps" in the upper bed of No. 1 mine the chief manifestation was through the breaking of timber and release of the soft "rash" and coal above it. The immediate roof in some cases may be permanently lowered by such a hammer-like blow, and in the recent "bumps" in No. 1 mine there were indications from the timbering that in places the immediate roof had been smashed down 3 or 4 inches.

The great danger to the workmen is in being buried by the loose material, which in the case of No. 1 mine lies above the usual timbering, or from the sudden thrusting-up of the floor against the roof or side, as was the manifestation in the No. 2 mine in the "bumps" of 1908-8. The slabbing of coal from the entry ribs is a contributory factor to the danger of the miners, and in the case of the "bumps" in No. 2 the giving of large amounts of gas was an additional danger.

Another secondary but dangerous condition for the men in the area affected was, in the greater No. 1 mine "bumps" recently, due to falls of roof which suddenly blocked the air-current, and this sudden arrest of a large column of air 4,000 lineal feet long, actuated by a pressure measured by several inches of water-gauge, caused the bursting-in of many wood ventilating stoppings at the head of the "main intaking" entry, and built up a momentary pressure which hurled the men in its path in reverse direction to the former current.

Occurrence of "Bumps" in other Mining Districts.

"Bumps" are known in other coal-mining districts of the world. They have been a serious menace in a certain South Staffordshire coal-mine in Great Britain working the "10-yard seam" 21 to 30 feet thick. This mine is worked by a square chamber system, and, the pillars being very high, there is probably some crush and subsidence of the immediate roof, opening an equivalent space at some unknown distance above. The strong rocks higher up, which are no longer able to span such areas of subsidence, break and cause "bumps." In these mines, when strong "bumps" occur, the timber is broken down and the coal slabs off and accidents to miners are caused thereby. In the case of the South Staffordshire mines the coal and strata have low dips and the overlying surface is practically level, the depth of the workings being about 1,500 feet or more from the surface.

In the United States "bumps" are reported to have occurred in certain coal-mines of Utah, working under the Book Cliff mountain, where the depth of cover has been 2,000 feet or over.

There have also been occurrences of "bumps" in the Carbonado mines in the State of Washington leading to fatalities. These mines are working under the shoulder of the foot-hills of Mount Rainier, and where the total cover is over 2,000 feet. The measures dip from 50 to 60 degrees at the outcrop to 15 to 20 degrees in the lower workings. The coal is mined by the room-and-pillar method, the rooms going up the dip and the coal dropped down by chutes to the level below. As soon as the rooms have gone up the proper distance, the pillars are sliced off so that at the head of an entry or level there are several rooms being driven up and several rooms outby in which the pillars are being drawn.

The floor and the roof are both hard, and in this respect the conditions differ from those at Fernie. Formerly little attention was paid to driving the rooms straight, with the result that there were sometimes very large pillars, and again sometimes small ones. It is believed that in this case the larger pillar held up the immediate roof while drawing the adjacent pillars; but when the weight on the larger pillars became such that they would no longer withstand the load they would suddenly crush down a little bit, breaking timbers, slabbing off coal, and in this way men were caught by the timbers or the coal. To meet this the operating company are now laying off the pillars regularly, and during the recent months the mine had been free from any "bumps." Whether or not a final cure has been effected still remains to be seen.

The problem of the "bumps" in the Crowsnest field is not confined to the Coal Creek area alone, but, from the natural conditions surrounding the field, similar difficulties threaten in the future all extensive mining operations, as the mines get under deeper cover, unless some system of mining can be evolved that will prevent the "bumps" from occurring.

Proposed Lay-out for Future Workings to lessen Hazard of "Bumps."

Before leaving Fernie after investigation of the mining conditions, the writer had a conference with the following gentlemen: Mr. Wilson, General Manager; Mr. Robertson, Provincial Mineralogist; Mr. Graham, Chief Mine Inspector; Mr. Williams, Inspector of the Coal Creek District; and Mr. O'Brien, Inspector of the Michel District. After a discussion of the phenomena of "bumps" and the danger to employees and property therefrom, Mr. Wilson was requested to give his view as to what would be the best method of avoiding the dangers of "bumps." He presented the following general plan:—

To reopen the main entries through the temporarily prohibited area and drive them on until the selected boundary of the mine is reached, when retreat would begin; to also drive a pair of parallel rooms on either side for airways, making six advance entries and airways extending into the coalfield; off the main entry there would be turned at right angles side entries every 800 feet, and from these would be turned pairs of rooms, each room of the pair 60 feet apart centre to centre, and each pair of rooms to be 200 feet apart. The rooms to be driven 600 feet, thus leaving a barrier pillar of 200 feet between the ends of rooms off one pair of entries and the ends of rooms off the next pair of entries inby. Under this plan only one-eighth or a little over 12 per cent. of the coal would be extracted in advance. The idea expressed by Mr. Wilson was to take out enough coal to develop the ground and to partially pay for advancing the entries. (*See* dotted lines on map (Exhibit 4) and sketch (Exhibit 8).) When the boundary of the district to be worked from the mine was reached, then a retreating system of some sort would be employed. Meantime it would be necessary to very much enlarge the ventilating system so as to adequately take care of the increased flow of gas which might be expected in future.

The No. 2 mine (in the lower bed) was to be extended from the present main entries and two pairs of rooms on either side also extended for air-courses; these extensions to be parallel with the workings in No. 1 mine (off the upper bed). The No. 3 mine on the lower bed was to connect by cross-entries with the No. 2 mine, which lies to the west of No. 3. The No. 3 Main level and air-course would have six parallel rooms running approximately on water-level southward. There would, of course, have to be some local modifications of the various plans to fit the natural conditions.

The general scheme is shown on the map (Exhibit 4), which is a contour map of the coalfields, showing several Coal Creek mines on the south side superposed and the proposed extension working in dots. This proposed plan was drawn up subsequent to the conference and copies given to the writer and the Provincial authorities.

REVIEW OF EVIDENCE REGARDING CAUSES OF "BUMPS."

Before proceeding to a consideration of the means that may be taken to avoid or lessen the danger from "bumps," it seems advisable to summarize the evidence regarding them.

(1.) "Bumps" occurred in No. 2 mine in 1907-8 in a certain area, about 35 acres in extent, and over which there was about 2,000 to 2,700 feet of cover. These "bumps" were manifested in the sudden upheaval of ground at local points and the giving-off of large quantities of methane, which smothered the men entrapped by the upheaved bottom. At this time the bed above this (No. 1 bed) had not been opened in this vicinity.

(2.) In November, 1916, "bumps" occurred in No. 1 East mine in bed No. 1 in an area 150 feet vertically above No. 2 mine, almost directly above, but a little inby the bump area in the lower mine. (*See* Exhibits 4 and 5.) These "bumps" were manifested in the upper mine by the breaking of timbering and throwing-down of false top, rash, and roof coal, but without noticeable discharge of gas and without affecting the floor. As the No. 2 mine under the bump area was closed, effects could not be observed, but inspection of the boundary district surrounding the Old No. 2 mine disclosed only such slight and doubtful evidence of a few cracked timbers at a couple of points as to be negligible. Men in No. 3 mine heard the crash of the "bump," but were not injured and no falls occurred.

(3.) In No. 2 bed floor was the weakest part of the seam. From 50 to 60 per cent. of the coal had been mined out in the bump area in that bed, throwing a heavy load upon the pillars. In the upper bed the weakest portion of the stratum was the rash-band and loose roof-coal.

(4.) "Bumps" in coal mines are known in various coal-mining districts of the world, and are akin to air-blasts in metal-mines, which are of serious account in the deep mines of the Rand and in the Lake Superior copper-mines.

(5.) "Bumps" occur only where there are rigid massive rocks like conglomerates, limestone, and massive sandstone in the cover over a mine, and also occur only when the workings are at great depth—that is, 1,000 feet or more.

(6.) There is great danger to underground workers as well as serious danger to the mine itself from "bumps" of a magnitude like those which have occurred; that comparatively few men have been killed is a fortunate circumstance; because, for example, if the great "bump" of November 8th, 1916, which threw down the rash and roof coal through an area of 30 or 40 acres, had occurred during the day shift, several hundred men would have been exposed to the danger of being buried or smothered by the thick dust which filled the atmosphere.

(7.) The roof of No. 2 mine is strong, and it is reported that it was not affected by the "bumps" which occurred in 1907-8. In No. 1 mine the false top, with rash and roof coal, was weak, but the main roof is strong, and close observation, so far as the heavy falls permitted inspection after the great "bumps" of November, did not disclose any weakening of the main roof.

CONCLUSIONS FROM EVIDENCE REGARDING "BUMPS."

Your investigator believes:—

(*a.*) That "air-blasts" are the result of great areas of unsupported mine-roof or hanging-wall giving way suddenly, like an overloaded bridge, and thus causing a blast of air from the collapsed workings.

(*b.*) That "bumps" only occur when there is deep cover over the mine and where there has been a subsidence of the roof over an excavation or squeezed area; the rigid strata above has not flexed downward, but spans the sunken area. When the span, through continued mining and widespread subsidence, becomes too great for the rock stratum to bridge over, enormous masses may fall, and while the distance may be only a few feet or even a few inches, the sudden arrest of rock-masses weighing possibly thousands of tons will set up a shock-wave in the underlying stratum which gives the effect of a local earthquake.

(*c.*) That after one rigid stratum has given way in the interior of the measures there is opportunity for similar giving way of successively higher strata, but, it is thought, with less and less effect on the mine-workings as the spaces become more or less filled with broken rock and the blow cushioned, also as the vertical distance above the workings becomes greater with each successive fall.

(*d.*) It is believed that had the massive rock cover been frequently broken in mining No. 2 mine from the outcrop, which usually takes place in mining, by the long-wall advancing method, "bumps" would not have occurred. One piece of supporting evidence for this belief is that on the North side, where such long-wall work is done, the cover was broken over the mine for a height of 1,200 feet vertically without causing any "bump" effects.

(*e.*) It is also believed that, using the pillar-and-stall or pillar-and-room method, had the advance mining been as systematic as at present and not taken out to exceed 25 per cent. of the coal, the weight thrown on the pillars would not have been great enough to cause their being crushed into the floor, and probably the "bumps" of 1907-8 would not have occurred.

(*f.*) It is believed that the condition of subsidence brought about in the "bump" area of No. 2 mine is directly responsible for the "bumps" affecting the No. 1 mine; in other words, had the No. 2 bed been unworked, the "bumps" would not have occurred from the method of mining carried on in the No. 1 mine. It was contended that there was no evidence of subsidence or settlement in driving the No. 1 entries and rooms. The writer's experience is that, with 150 feet intervening between the coal-beds and flexible strata, any previous movement in sinking several feet would not be discernible in the coal or shales.

(*g.*) That, had the rash and top coal of No. 1 East mine been taken down, there would have been little damage done to the mine by the "bumps" and comparatively little danger to the employees underground.

(*h.*) That, in going into undisturbed ground beyond the No. 2 mine subsided area, the danger of further "bumps" would be reduced to a minimum, provided at least 75 per cent., and preferably 80 per cent., of the coal is left intact and the pillars not withdrawn until the mine is retreating.

FUTURE REMEDY FOR "BUMPS."

The plan now proposed by Mr. Wilson, General Manager of the Crow's Nest Coal Company, after conference with Messrs. Robertson, Graham, and the writer, as shown by the dotted lines on the attached plan (Exhibit 4), under which system less than 15 per cent. of the coal will be taken out in advance, is a satisfactory method; provided that for the protection of the employees in No. 1 mine the rash and roof coal is taken down to a point as near to the face as practicable, for it cannot be assured that lesser "bumps" from breaking and dropping of rocks higher up may not continue; but by taking this precaution it is not probable that when a "bump" occurs any one would be injured.

It has been contended that there are difficulties in taking down the rash and top coal on account of a mixture of impurity with the coal, which would in turn seriously damage the coke. It would seem that this could be done by mining out the roof-coal in advance, putting up necessary timbers to support the main roof; then taking out the rash and filling same in rooms farther back; after this, mining out the main coal and putting in longer posts to catch the collars put in while working out the top coal. (*See* sketches by author, Exhibits 6 and 7.) Your investigator recommends ' 'al of the system to determine if practical, and, if not, some other plan which gives the de .. degree of safety may be developed.

An alternate plan, proposed by the operating company for room-work, is to first mine out the main coal in the rooms, and then drop the rash and top coal by pulling out the timbers. The objection to this is that until further advance, well beyond the present "bump" area, is made with immunity from "bumps," the majority of the miners would be exposed to burying or smothering if a great "bump" occurred. While, on the other hand, where the rash and roof had been taken down as shown wherever done in the main entry of No. 1 mine, no breakage of timber or falls had occurred.

REVIEW OF EVIDENCE REGARDING THE GAS AND OUTBURSTS OF SAME.

The problem of equal importance in working the Crowsnest field coals, and especially in future developments under deeper cover and greater distance from the outcrop, is to adequately take care of the large quantity of gas. Very wisely the mines are not allowed to equip with electricity for haulage or lighting, as the danger is too great.

The following are the chief facts developed:—

(1.) That the flow of gas as measured by the analyses of the returns and the outbursts of gas which occurred at the Morrissey collieries show that the Crowsnest Pass coalfield mines are among the most gaseous in the world.

(2.) That gas is derived from two sources: (*a*) Stored in the crevices and joint-planes of rocks and coal; (*b*) occluded, or that held in the pores or cells of the coal or by surface tension.

(3.) That an unusual condition has been found in testing the amount and kind of gas given off by the broken coal, which, on the basis of one sample, shows: (*a*) That an unusual quantity of hydrocarbon gas is given off by the coal on grinding fine in vacuo; (*b*) that three times as much ethane and other hydrocarbons are given off as methane under these conditions.

(4.) That the gas-pressures within a short distance of the face of the workings are low, which, however, is not proof that high gas-pressures may not exist at a considerable distance in the solid away from the face.

RECOMMENDATIONS REGARDING GAS-FLOWS.

(*a*.) That since the gas-pressures rapidly lessen from about 18 lb. 21 feet from the face to nothing at the face of the coal, it is indicative of the importance of draining the coal-measures by advance headings.

(*b*.) To prevent the danger of outbursts overwhelming the men, as at Morrissey, it seems very desirable in faulty ground or crushed zone that drill-holes be kept in advance of the main heading, and in such ground that they be advanced at only a moderate rate—say, perhaps only one shift per twenty-four hours—in order to permit the slow draining of the gas.

(*c*.) That in those portions of the field which permit advancing long-wall this system should be used from the outcrop. Long-wall would probably prevent "bumps" and would drain the gas more slowly and more safely than pillar-and-stall work. However, advancing long-wall is not practicable with the conditions found in No. 1 East and No. 1 South at the present time, though probably it might be applied in the No. 2 bed.

RECOMMENDATIONS FOR COMMISSION OF INVESTIGATION.

It has been implied in a number of places in this report that there are obscure matters which can only be cleared up by further investigations. The research-work on gases, the recording of phenomena, such as rock-tremors, "bumps," and outbursts, and the trial of methods of mining. The importance of most of these matters is obvious from statements in the report, but the inquiries may be summarized as follows:

(1.) The making of careful topographic survey in the vicinity of all operating mines and the establishment of monuments in advance of mine-workings by precise methods of surveying, so that all changes may be observed, together with the observation and measurement of surface cracks which may develop.

(2.) The establishment of seismographs registering vertical waves at two or preferably three points on the face of the mountain above No. 1 South. If possible, these seismographs to be so connected up electrically that the registrations will be made at some suitable convenient point in the vicinity of the mine-mouth. It is believed that comparatively simple seismographs would be suitable for th urpose of determining in what horizon or stratum of the rock any disturbances were takin, :e, with the ultimate hope that some means of warning might be given apart from the matte. if scientific interest. It has been claimed (with what truth is not known) that seismographs are now being used on the battle-front in France to determine the location of the enemy's big guns.

(3.) The carrying-on of experimental methods of mining the coal at the face in a practical manner, especially in No. 1 bed, so as to lessen the danger in case of "bumps" or falls of rash and roof coal, and to look into the best method of timbering for protection.

(4.) In the matter of occluded gas, to gather samples in various beds, and in conjunction with labo tory testing to determine the amount of occluded gas in different coal-beds, how it is held, and if there is any chemical instability which might or might not be connected with any shrinkage of the coal in place in the pillars of the mine-workings. In this connection plugs or monuments in the roof, sides, ribs, and floor might be established at various points in the mine to determine whether or not movement or shrinkage is going on.

(5.) In the matter of protection from fire-damp, to continue the excellent investigations begun and carried on during the past two years by the Provincial Inspection Department of gathering samples of mine-air as to dangerous conditions in any part of the mine, and to obtain data on the drainage of the gases from the coal-bed, such work being planned with the special view to determine the relative amounts of gas given off in various localities, also when the mine is working and when it is idle.

(6.) To drill a number of long boreholes, say 100 feet or more, in advance of the working-faces to determine the amount of gas given off from a given exposure of surface of the borehole at the inner end, left unpacked, say 3, 4, or 10 feet, as the case might be; also to record the gas-pressure at regular intervals from the inner end of the hole to its mouth, and thus obtain a curve of fall of pressure from the interior of the unmined coal to the face of the mine. The practical object of this would be to determine the rate at which it would be wise to allow the entries to advance, and also to determine if the gas in dangerous areas, as in crumpled, crushed zones, could not be bled off by means of such boreholes, cased or otherwise, as in the very dangerous conditions found in the Carbonado mines at Morrissey. It is your :nve :i tor's opinion that the question of methane flow and pressure is going to be of an increasingly serious nature in all of the mines in the Crowsnest field as they penetrate farther under cover.

(7.) The greatest function of such a permanent commission would be to determine how the collieries may be so laid out under the difficult conditions which confront mining operations in the Crowsnest field that all the coal which is now considered as a "reserve" may be ultimately obtained. When it is recalled that it is practically impossible to sink shafts into the larger part of the field, and that, if the coal has to be attacked from the outcrop, to mine in the interior of the field will re · entries or tunnels six, eight, or ten miles in length, the magnitude of the problem is a

In conclusion, mend too highly the admirable attitude taken by the officials of your Province, the eralogist, Mr. Robertson, and the Chief Inspector of Mines, Mr. Graham, in regard ns which confront them. Their past action in safeguarding the miners and property by orders received my hearty approval. But in such problems as will confront them in future, in the matter of making the mines safe for the employees and in obtaining the highest yield from the coalfields under the very difficult natural conditions, it is important that they shall have the opportunity of conferring with and receiving the advice of a commission of ability, and which has members who can speak with authority on scientific and technical subjects. It therefore seems advisable to have on such a commission a geologist, a mining engineer, a chemist, and an experienced mine operator.

Respectfully submitted.

GEORGE S. RICE.

Washington, D.C., March 26th, 1917.

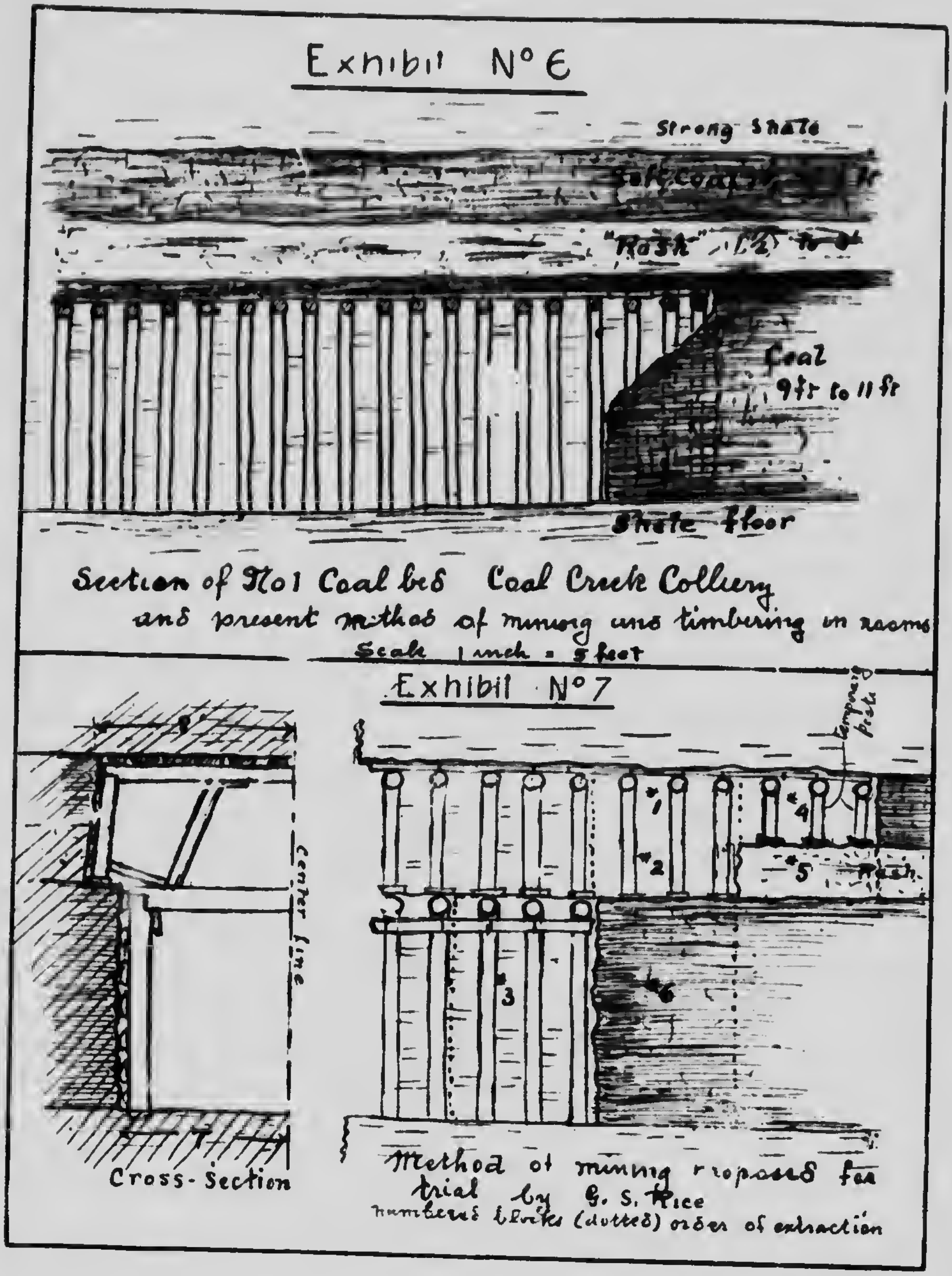
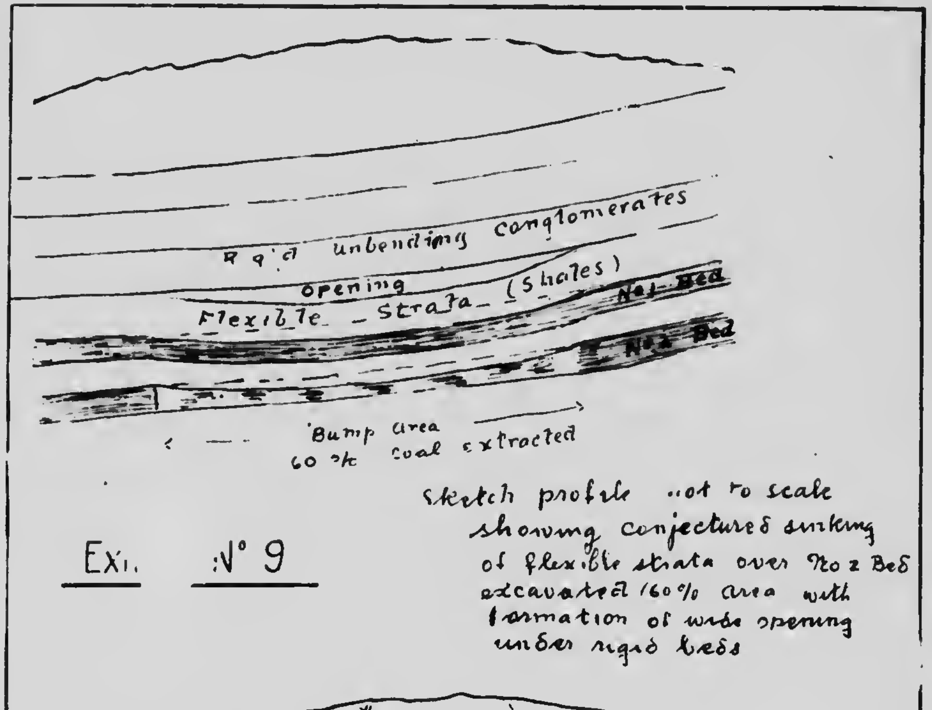
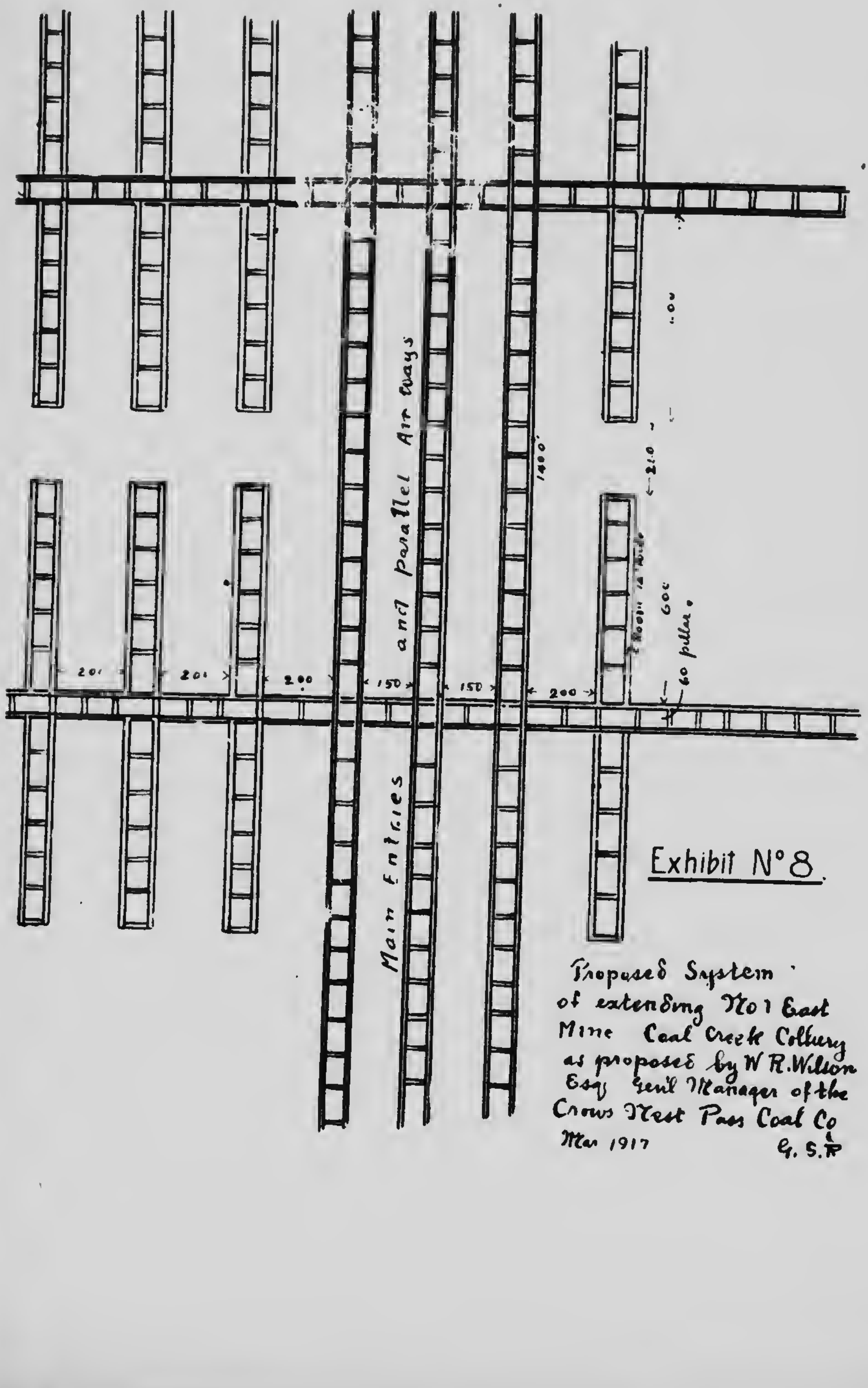


Exhibit No 6
Strong Shale
"Rash"
Coal
9 ft to 11 ft
Shale floor
Section of No 1 Coal bed Coal Creek Colliery
and present method of mining and timbering in rooms
Scale 1 inch = 5 feet
Exhibit No 7
Center line
Cross-Section
1
2
3
4
5
6
Rash
Method of mining proposed for trial by G. S. Rice
numbered blocks (dotted) order of extraction


Rigid unbending conglomerates
opening
Flexible Strata (Shales)
No 1 Bed
No 2 Bed
Bump area
60% coal extracted
Sketch profile not to scale showing conjectured sinking of flexible strata over No 2 Bed excavated (60% area with formation of wide opening under rigid beds
Ex. No 9
#4
#5
#3
#5
#2
#1
Secondary stages showing breaking of rigid bed successively until spaces are filled or surface reached The successive falls causing bump in mines below
Geo S Rice

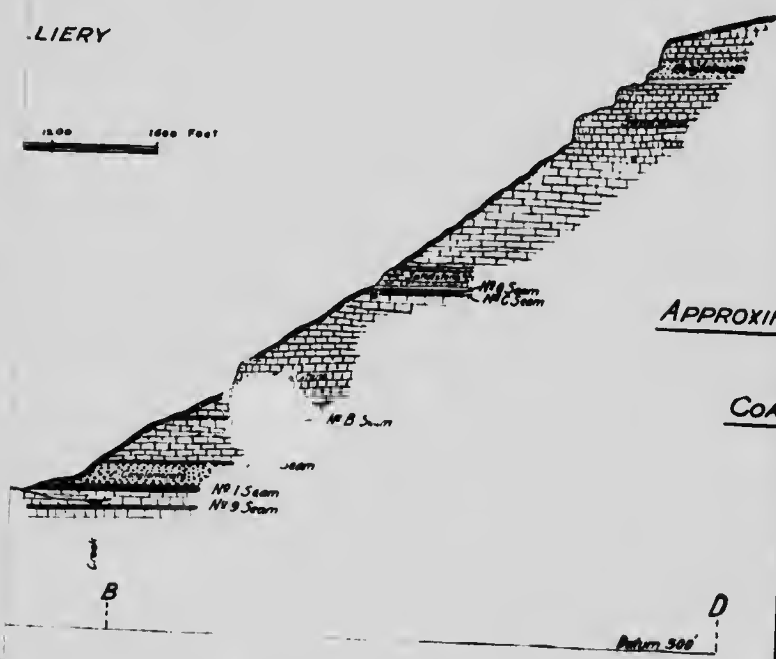

Main Entries and parallel Air Ways
1400'
200
150
150
200
60 pillar
Exhibit N°8.
Proposed System
of extending No 1 East
Mine Coal Creek Colliery
as proposed by W R. Wilson
Esq Gen'l Manager of the
Crows Nest Pass Coal Co
Mar 1917
G. S. R

2

…AL FORMATION

…LLIERY

1200 1600 Feet

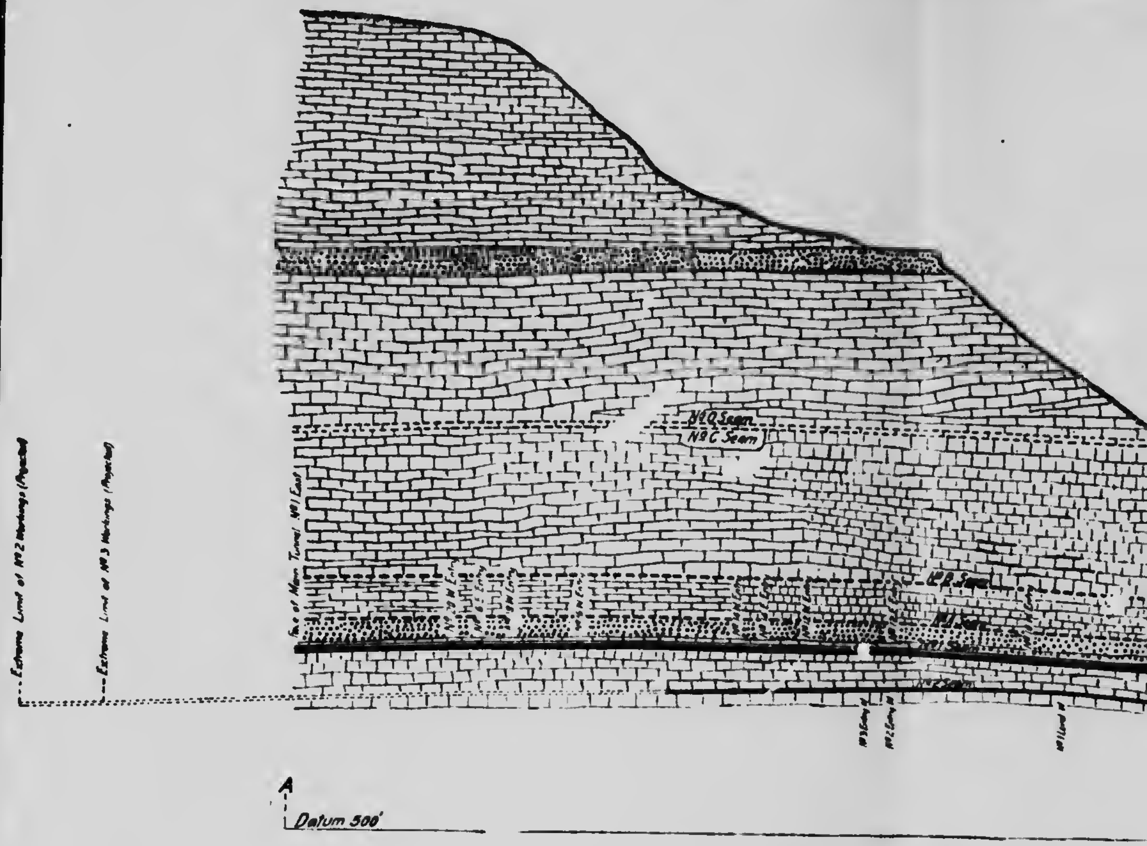


APPROXIM…

COA…

…CTION C-D SHOWS COVER OVER SEAMS ON NORTH SIDE

…he above section was taken 800 feet West of the No 1 East Main Tunnel. Mag N26°06'W



SECTION A-B SHOWS COVER OVER No 1 E

Magnetic North

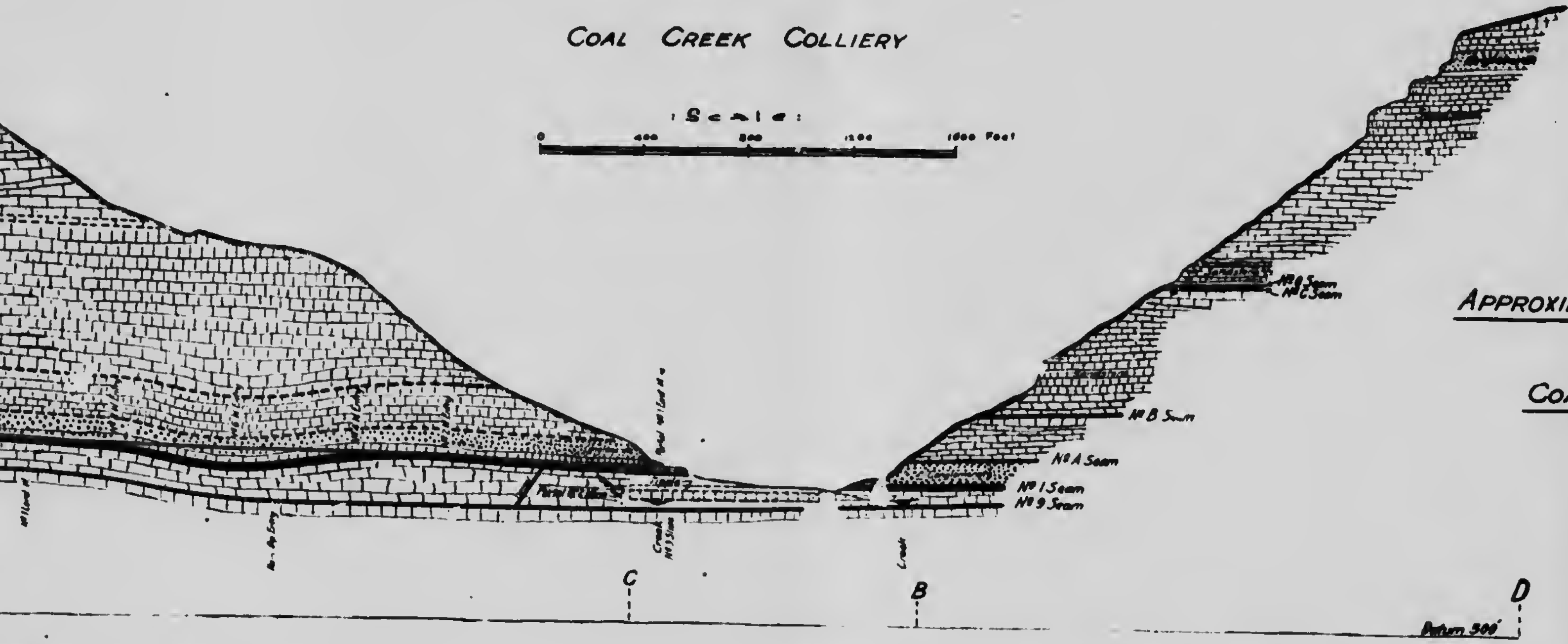
EXHIBIT 2

SECTION OF

APPROXIMATE GEOLOGICAL FORMATION

AT

COAL CREEK COLLIERY

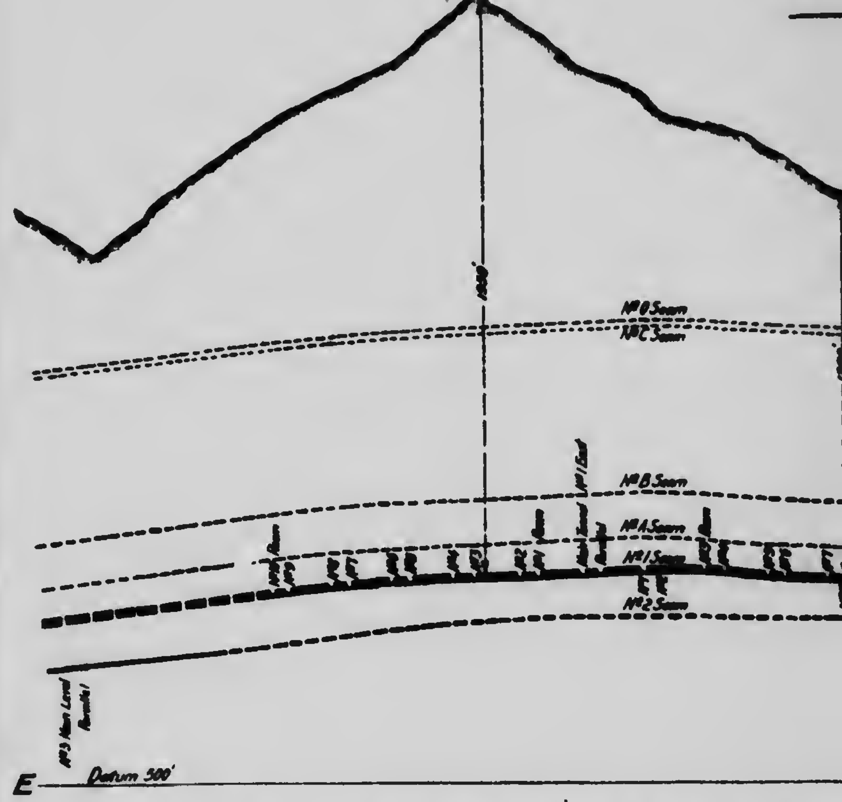


...ER Nº 1 EAST MAIN TUNNEL

SECTION C-D SHOWS COVER OVER SEAMS ON NORTH SIDE

The above section was taken 800 feet West of the Nº 1 East Main Tunnel. Mag N 26°45' W

EXH



This Section taken 300 ft South and parallel to No 14 East Entry and

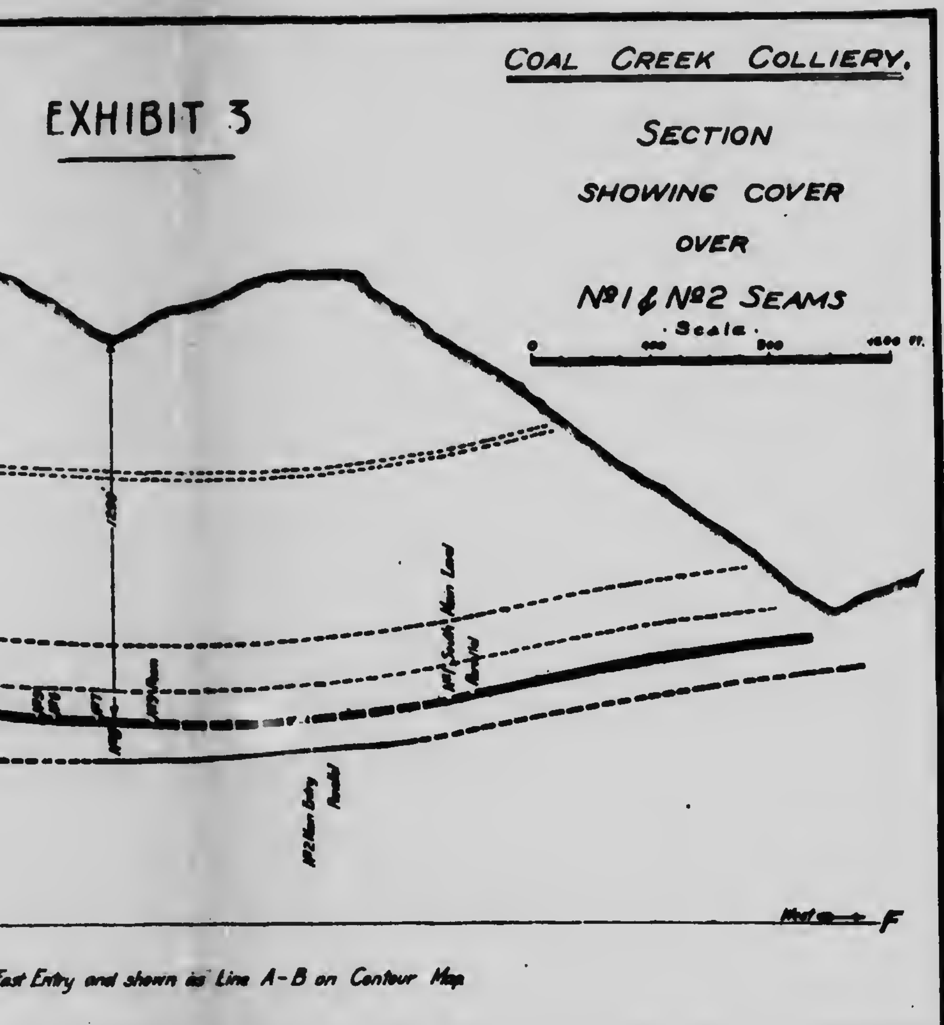
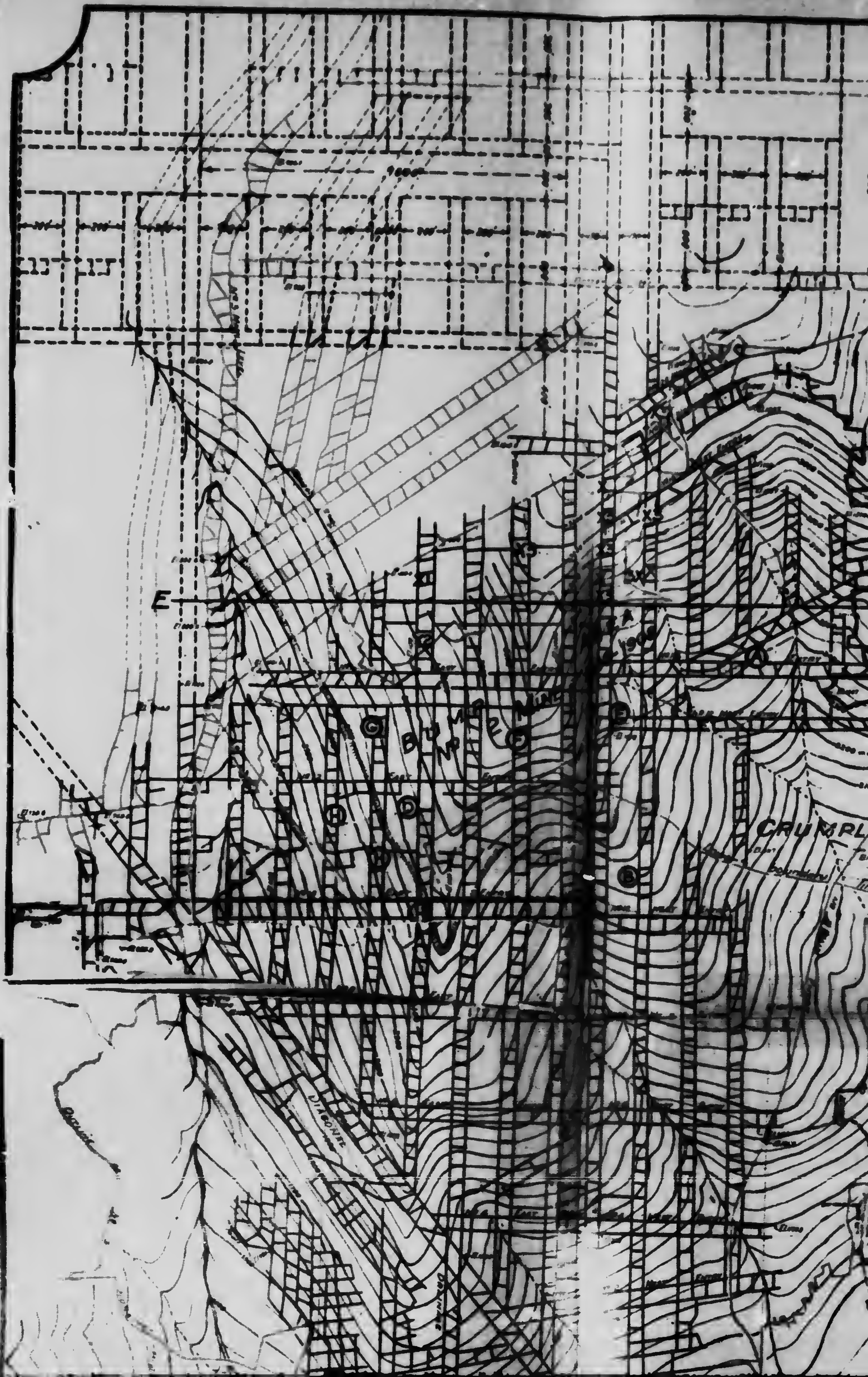
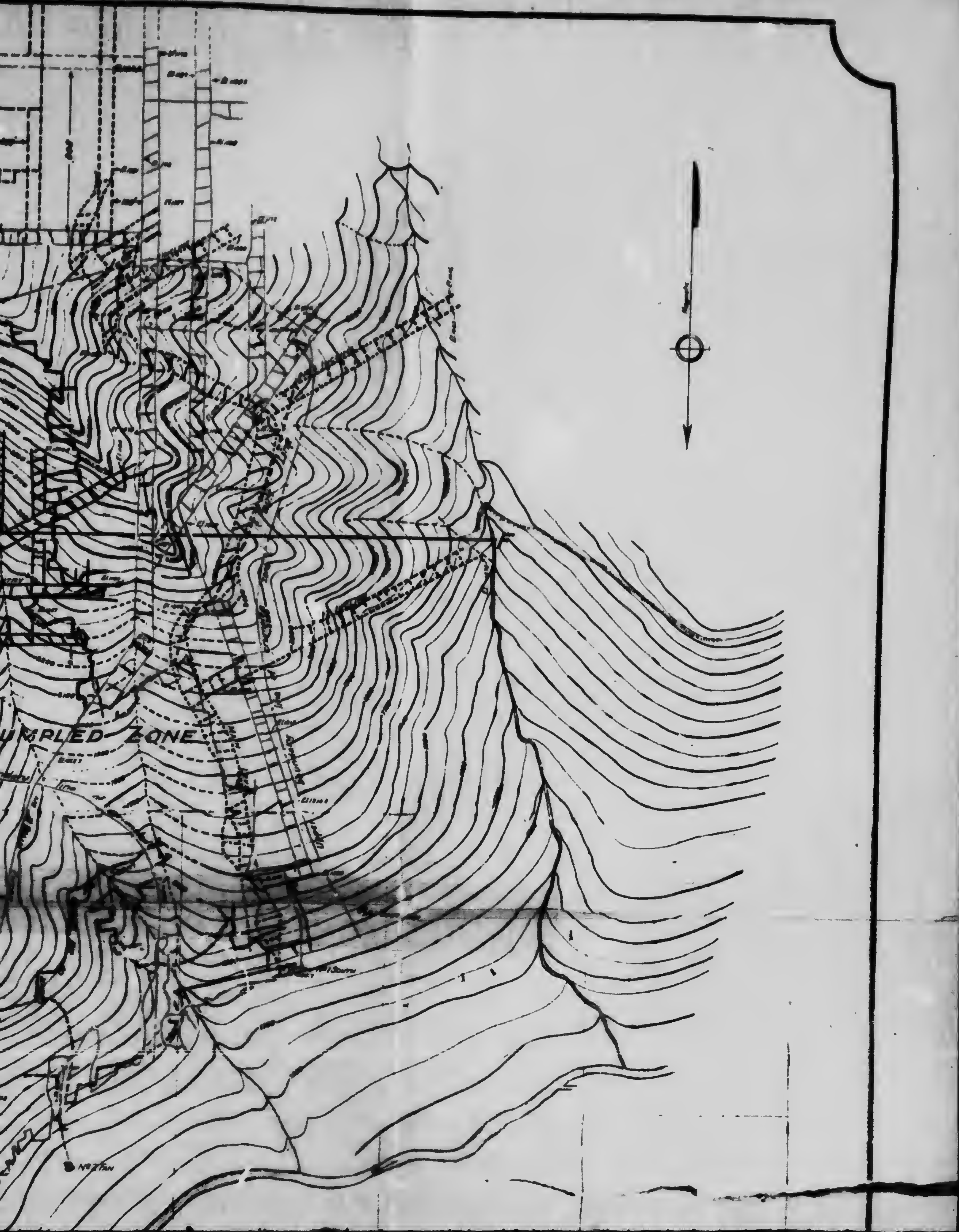


EXHIBIT 3
COAL CREEK COLLIERY.
SECTION
SHOWING COVER
OVER
No1 & No2 SEAMS
Scale
F
East Entry and shown as Line A-B on Contour Map



E
CRUMPL



UMPLED ZONE

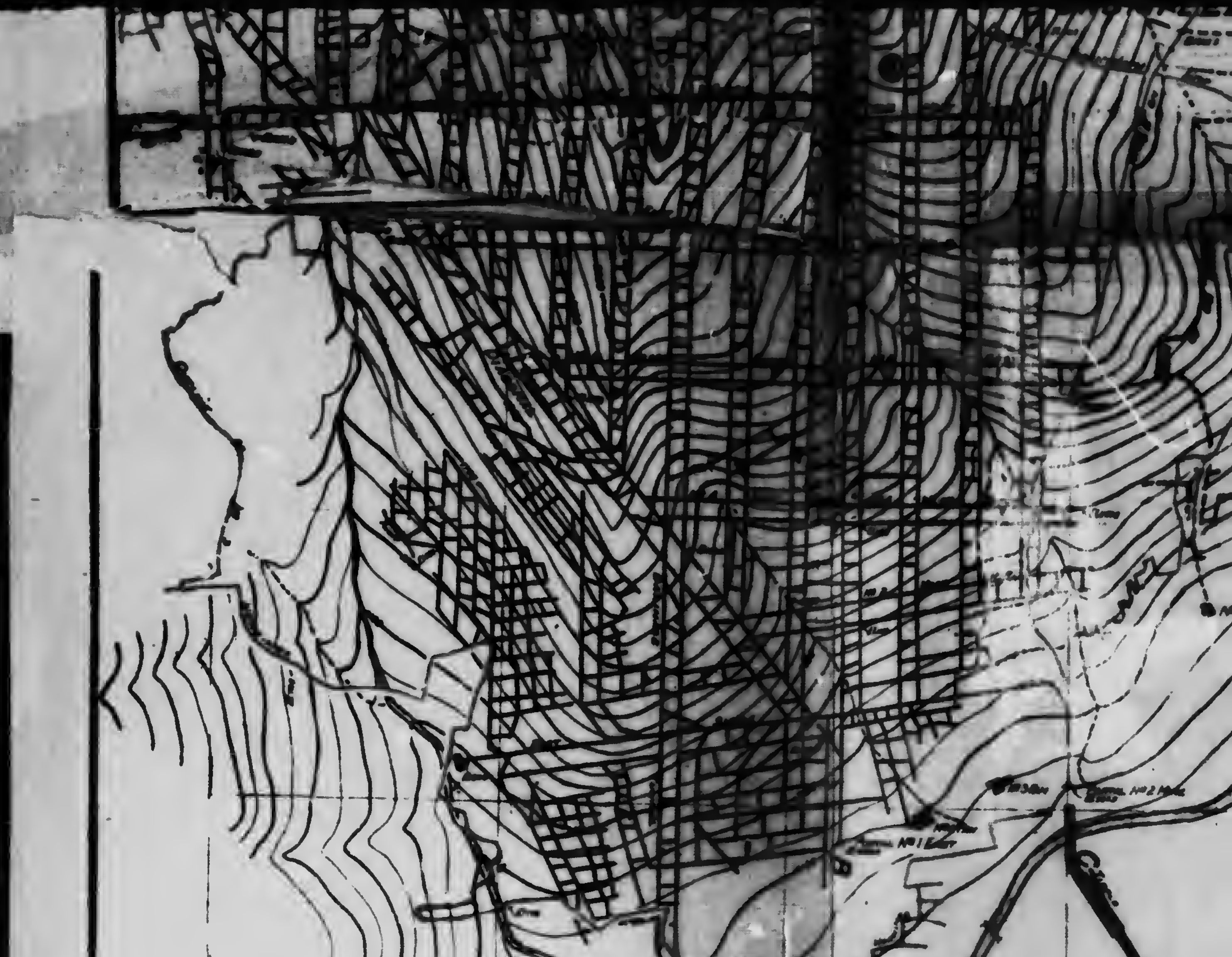

1906 - 1908
1916

Exhibit Number 4.
CONTOUR MAP
COAL CREEK COLLIERY
SCALE:- 1 INCH - 400 FEET
LEGEND
Nº 1 EAST MINE SHOWN
Nº 2 & 3
Nº 1 SOUTH

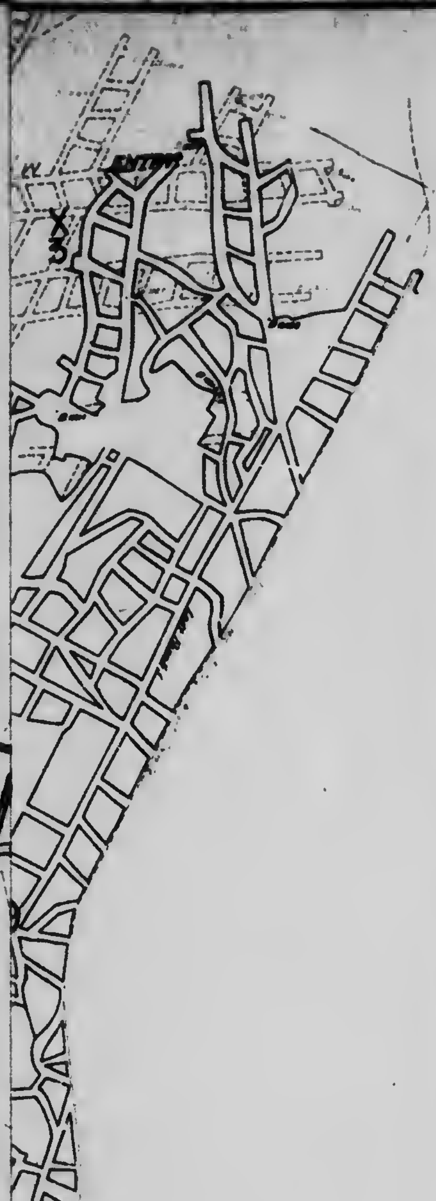


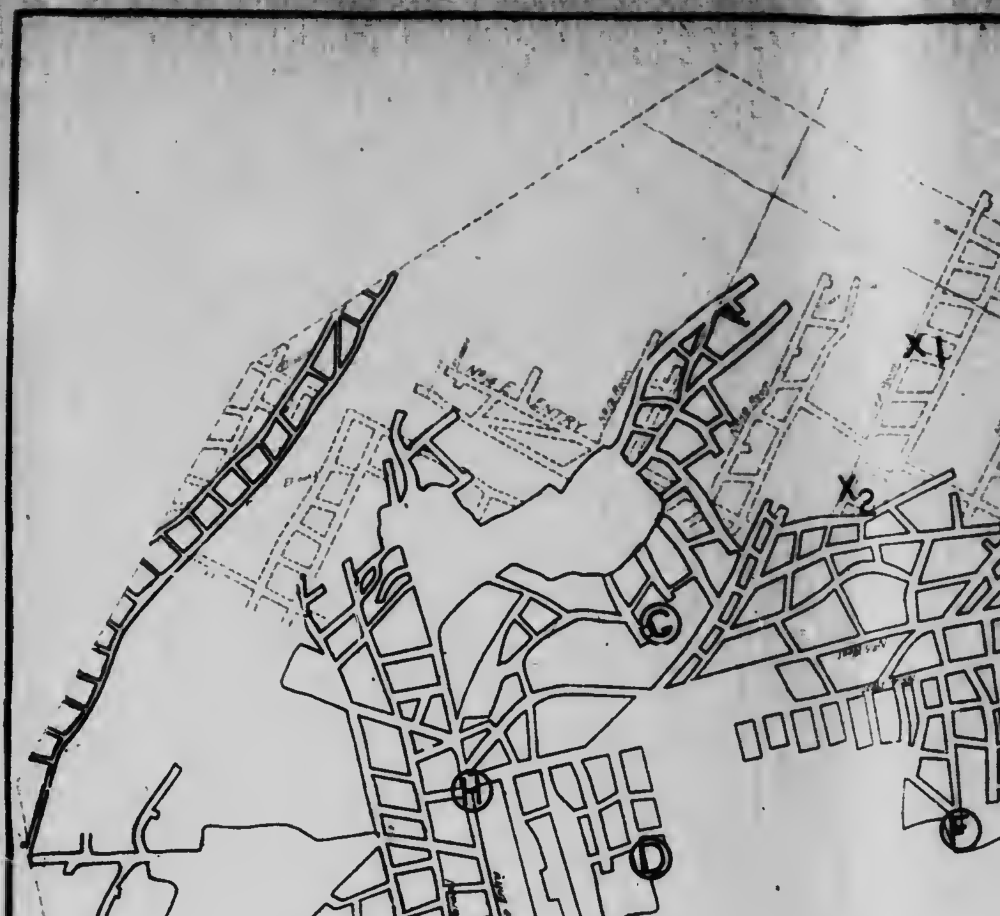
Exhibit N° 5

N° 1 East Mine

N° 2 & 3 Mines

(A) 1906 - 1908

X 1916



X1
X2
ENTRY
C
H
D
F
H
H

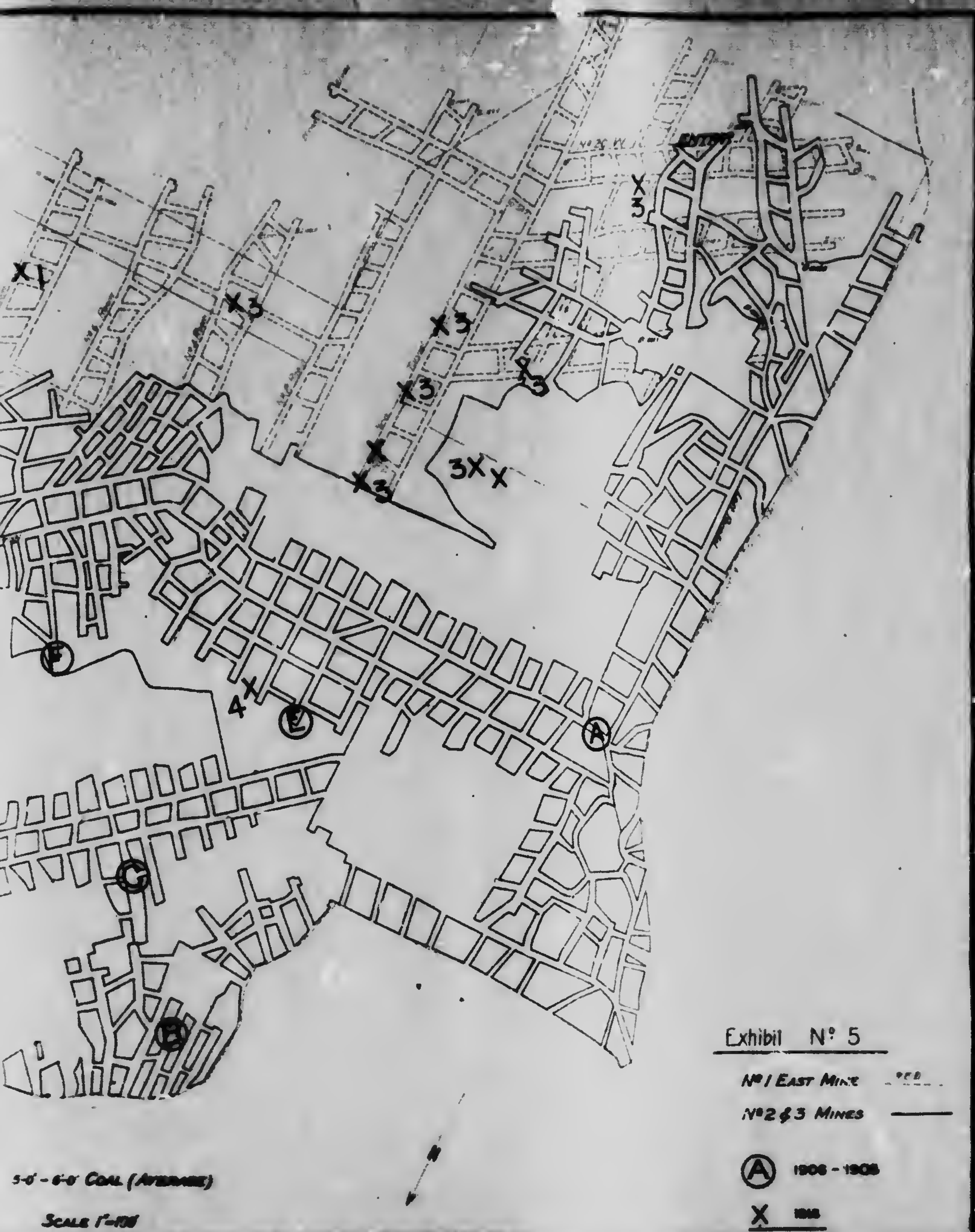


Exhibit Nº 5
Nº 1 East Mine
Nº 2 & 3 Mines
A
Coal
Scale