OCCURRENCE OF OUTBURSTS AT WEST CLIFF COLLIERY

By

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ABSTRACT

West Cliff Colliery mines Bulli Seam occurring at a depth of approximately 480 m. The Seam is intersected by a number of small shear zones and faults. While the faults have caused displacement of the seam, the shear zones are strike-slip structures with small apparent displacement of seam. Outbursts at West Cliff Colliery occur while driving through these shear zones. Few outburst wave occurred where faults have been intersected.

In the last 3 years, over one hundred outbursts have occurred at West Cliff Colliery. The size of outbursts varies from a small bump to exceeding 140 tonnes of coal. A number of studies have been undertaken at West Cliff Colliery to control outbursts and predict outbursts in advance of workings. These include: geological investigations, microseismic techniques, gas adsorption studies and gas drainage. The investigations to date suggest that outbursts of gas at West Cliff Colliery are more a gas phenomenon similar to what occurs in overseas mines. The results of various investigations are reported.

INTRODUCTION

West Cliff Colliery is located in the mid-west of the southern coal fields of N.S.W. Colliery holding lie between Coal Cliff (eastern end) and Appin colliery (western end). The colliery mines high quality coal from the Bulli seam (top seam of the Illawara coal measures) at a depth of approximately 480 m. The average thickness of the coal seam is 2.5 m with some minor variations. The immediate roof of the Bulli seam consists of Coal Cliff sandstone, a fine to medium grained sandstone containing occasional conglomerate and shaley bands. The sandstone generally ranges from 5-10 m in thickness. Towards the western limits of the colliery holding the immediate roof becomes shale.

Two large faults, namely the Four Mile Fault and the Stokes Fault, are predicted in the eastern part of the lease. These parallel faults, running NW-SE will probably form the eastern boundary of the colliery. A number of minor dip-slip faults running NE-SW occur in the seam, and at some places have displaced it up to a maximum of 10 m (southern section) but most of the faults are much smaller (< 1 m). The seam is intersected by a number of shear zones (strike-slip faults) running E-W. These are zones of large scale pulverisation of coal and form foci of outburst of gas and coal. The seam dips at 1 in 40 towards the NW. There are only minor changes in the dip direction and dip of the seam.

The colliery has produced 3.2 million tonnes of coal (ROM) since operations began in 1976. A major portion of this coal has come from first workings (development drivages) using conventional

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continuous miners and shuttlecars. The major development axes of the colliery are east-west and north-south. The pillar size varies between 60 x 40 m and 40 x 40 m with 5.5 m wide roadways. Extraction ratio during development has been approximately 25%.

The roof is supported using props and chemically bolted steel 'W' straps set at approximately 1 metre centres. Each 'W' strap is supported by four bolts. Roof conditions have in general been good, particularly where sandstone dominates. In the northern and western sections there has been some deterioration of roof, in the form of guttering, with associated floor heaving. Thinly laminated roof beds with predominance of shale occur in this part of the mine.

A number of panels have been extracted using "Wongawilli" split and fender retreating system. At this stage pillar extraction is planned to continue using this technique. There are plans, however, to adopt longwall retreating systems using chock shield support.

The seam gas is mostly methane in the southern and western sections. The composition of the gas changes to a mixture of methane and carbon dioxide to the east and north. In the northern headings gas samples collected from some boreholes have up to 75% carbon dioxide. Fig. 1 shows the results of gas analyses conducted on samples collected from surface boreholes in the general area. Changes in gas composition have been detected not only in the plane of the seam, but also with depth. In the West Cliff Colliery holding, no igneous activity has so far been proven in the Bulli seam or in the adjacent strata. Most outbursts, including all the larger ones, have been experienced in areas of the mine where the seam gas is predominantly methane. There is no evidence that the frequency and/or intensity of outbursts can be correlated with areas in the seam where a high percentage of carbon dioxide is present.

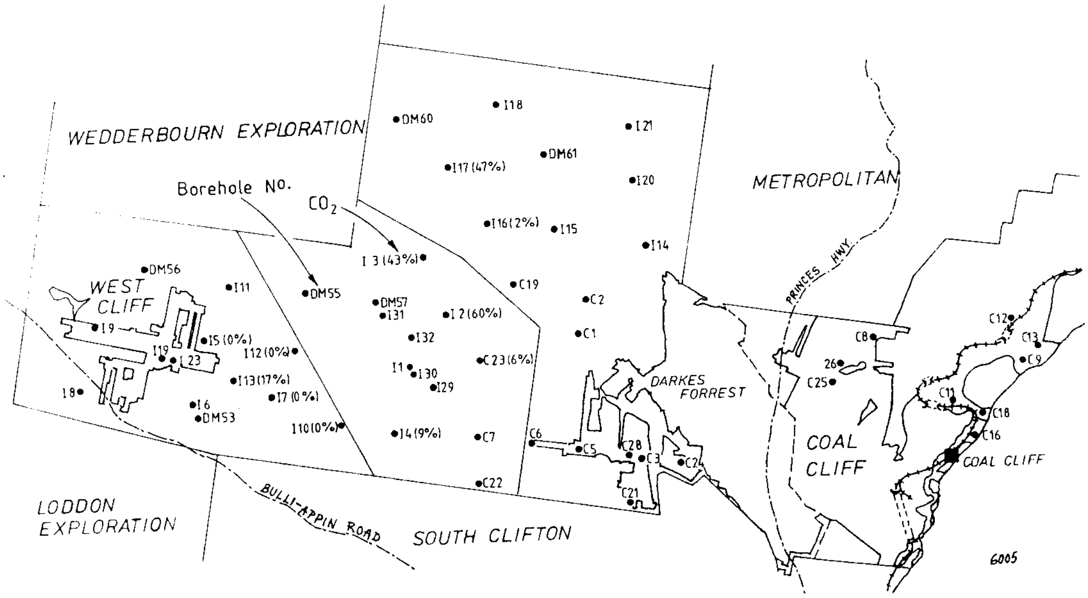


Fig. 1 - Location of West Cliff Colliery and percentage of gas as determined from borehole data (percentage of CO_2 is marked, remainder is CH_4) (Courtesy, P. Lamb 1980)

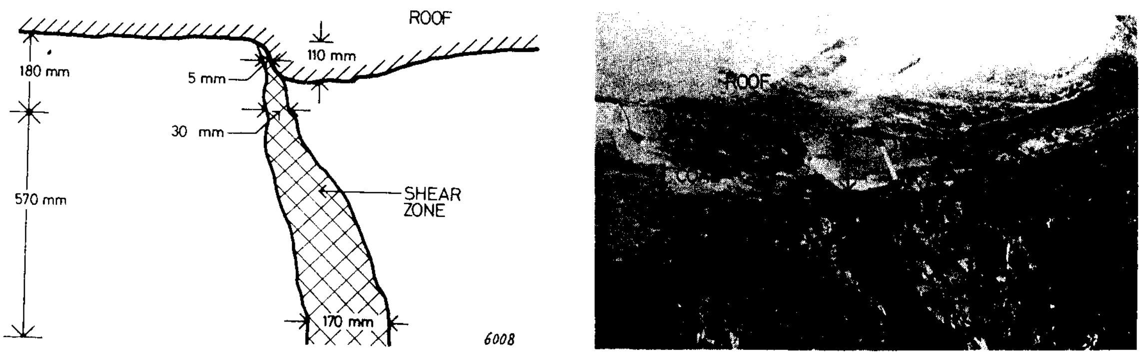
PROPERTIES OF FAULTS AND SHEAR ZONES

The first outburst occurred at the Colliery on 20 December 1976, and since then some 107 outbursts have occurred (till March 1980). A general plan of occurrences is given in Fig. 2. A striking feature of the outbursts at West Cliff Colliery is that they are all associated with geological disturbances occurring in the coal seam, in the form of shear zones running at about 100-110°. Displacement of the roof and floor in these shear zones is minimal, if not completely absent. At a few locations vertical displacement of approximately 110 mm has been measured (Fig. 3). The thickness of these shear zones varies from 30 to 1500 mm. The thickness of the sheared coal is much greater than the corresponding thickness of the shear zone in the floor or roof, and at places this could be almost 2-3 times that in the roof (Table 1). Increase in the thickness of the sheared coal can be either due to the effect of the outburst or to the difference in the properties of roof and floor rocks and coal seam. Limited measurements show, however, that the thickness of the highly pulverised coal does not seem to alter during the precipitation of outbursts, indicating thereby that very high stresses could not be acting during an outburst. However, this does not suggest that stresses don't play a role in outbursts at West Cliff Colliery.

The shear zones are not single joints but in fact a swarm of joints is associated with each one. The occurrence of some joint patterns close to the shear zones are shown in Fig. 4. Outside the shear zone, a number of joints have been found to run parallel to the main shear zone. These usually occur in a band form and lie at some distance from the shear zone. The distance between the joints vary from 2-5 cm (Fig. 5) and these have been measured up to two metres from the shear zone. They tend to be most prominent on one side of the shear zone. These are conspicuously absent in other places, and are apparently only associated with the shear zone. Roof falls occurring with outbursts, it seems, are associated with these swarms of parallel joints.

PROPERTIES OF OUTBURSTS

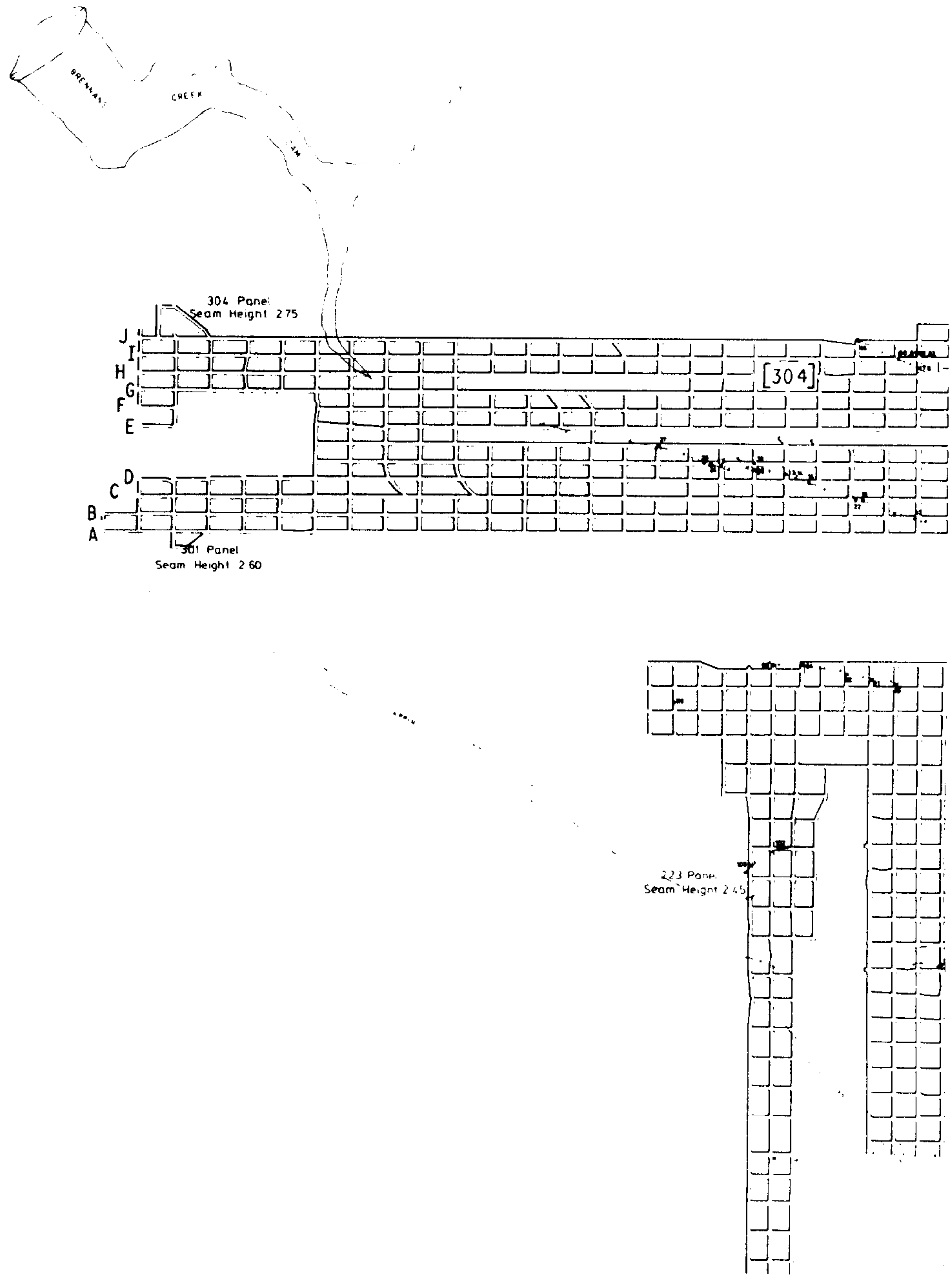
Most outbursts (> 95%) have occurred on the shear zones running along 100 - 110°. A few outbursts have been associated with a shear zone running at 80° (Panel 123).



(a) (b)

Fig. 3 - Vertical movement along a shear zone; Outburst Location No. 43.

Figure 2 Plan of West Cliff Colliery



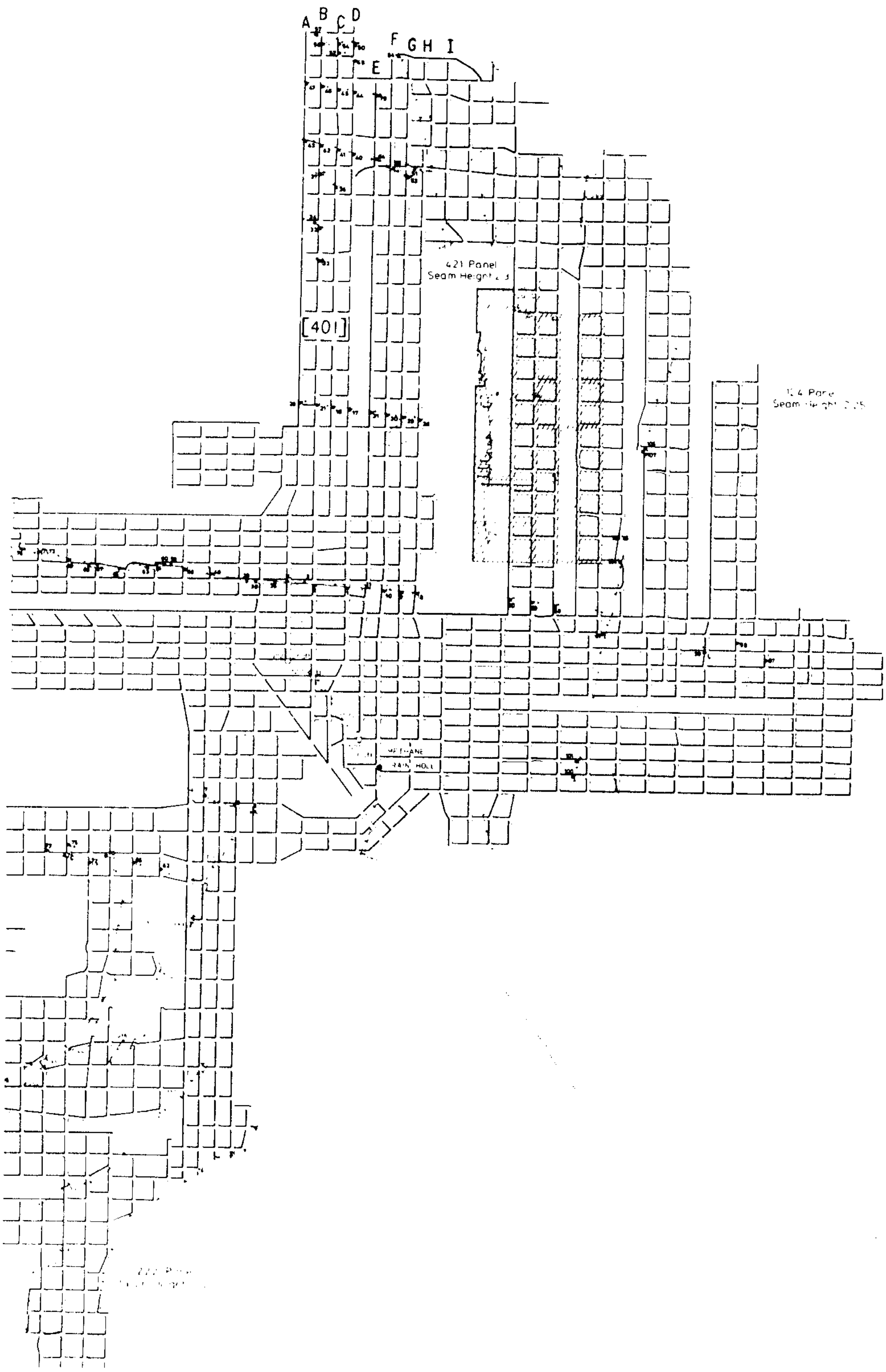

A B C D
E F G H I
421 Panel
[401]
METHANE
DRAIN HOLE

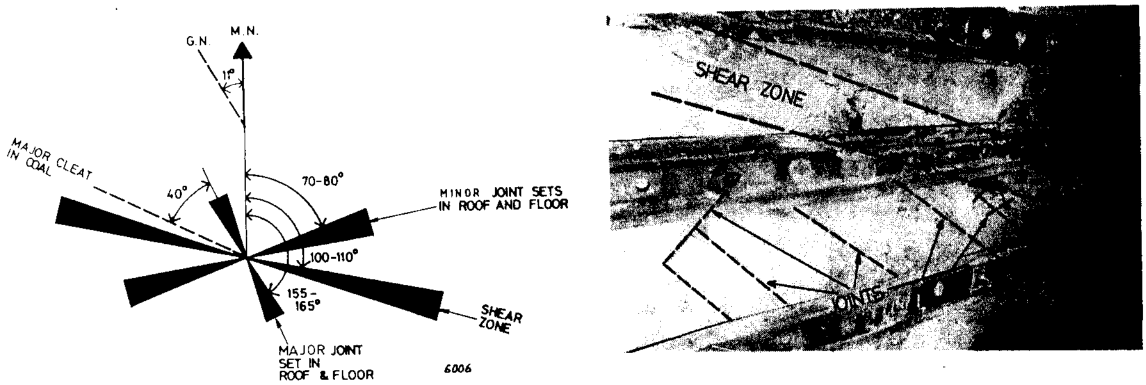
Table 1

Thickness of Shear Zone in Roof and Coal

Location	Thickness of shear zone in roof, mm	Thickness of shear zone in coal, mm
Panel 211 10 C/T West face	30	200*
Panel 211 10 C/T East face	25	30
Panel 211 11 C/T West face	310	500**
Panel 211 11 C/T East face	210	480
Panel 211 12 C/T West face	310	540
Panel 211 12 C/T East face	100	140
Panel 211 13 C/T West face	300	400*
Panel 211 13 C/T East face	220	380
Panel 211 14 C/T West face	200	550**
Panel 211 14 C/T East face	120	400*
Panel 211 15 C/T West face	60	220*
Panel 211 15 C/T East face	300	1100**
Panel 401 A 13 C/T West face	50	130**
Panel 401 B 1 outburst No.1	400	1360**
Panel 401 outburst No.1 West face	480	1484
Panel 401 outburst No.1 East face	420	880

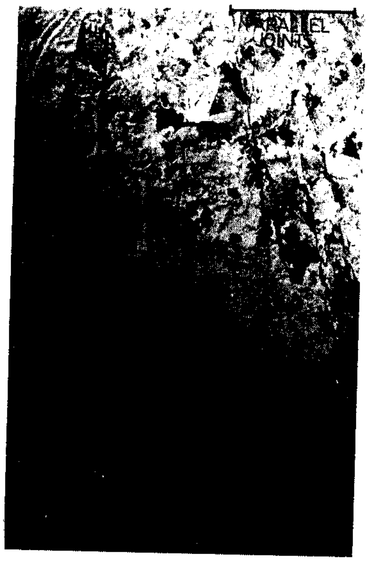
* minor outburst or collapse of coal

** large outburst

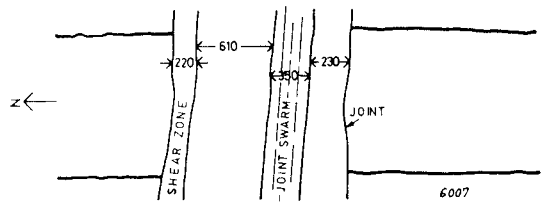


(a) (b)

Fig. 4. Shear zone and joint sets associated with it.



(a)



(b)

Fig. 5. Swarm of joints parallel to the shear zone; located at Outburst Site No.21.

The average quantity of coal displaced by outbursts has been 32 tonnes (Fig. 6). The largest of the outbursts displaced about 140 tonnes of coal. There have been no measurements of the amount of gas produced at the time of outbursting, however indications are that outbursts are not associated with very large

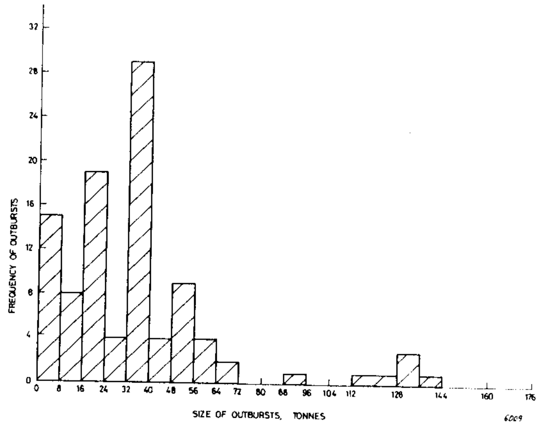


Fig. 6 - Frequency and size of outburst at West Cliff Colliery.

amounts of gas when measured in terms of cubic metres per tonne of coal displaced.

Closer study of the location of outbursts shows that the distance of 33 m (width of the pillar) is far too high to relieve the stress and gas pressure along the zone associated with an outburst, even after a span of 18 days. Heading B in panel 401 (Fig. 2) intersected a shear zone, giving an outburst on 17 June 1977 and displacing about 56 tonnes of coal with great violence. Heading A intersected the same shear zone approximately 40 m from the first intersection, causing another violent outburst and displacing 136 tonnes of coal, on 8 July 1977.

When a shear zone is intersected while driving in line with it, an average of 51 tonnes of coal is displaced in an outburst. This compares with 38 tonnes when the shear zone is intersected running at right angles to the axis of the roadways. The largest of the outbursts in both cases displaced approximately the same tonnage.

However, the higher intensity outburst (measured in terms of tonnage displaced) is not necessarily the more dangerous. In terms of safety of personnel, it might be expected that the shear zone when intersected across the full face of the roadway would be more dangerous, since it would result in complete dislodgement of the full width of the face, loss of immediate support, and possible collapse of the roof. However, the use of a full face continuous miner with a wide cutting head not only serves as a protection during an outburst precipitation, it works as a shield and offers resistance to the expanding coal face. This aspect is quite important and has been used in a number of countries (e.g. Poland, Hungary) as a means of combatting outbursts.

When a shear zone runs at an angle to the axis of the roadway, the location of the shear zone where it hits the sides of the roadway and the direction of drivage is important. Figs. 7 and 8 show typical cases of outbursts when a shear zone is running almost parallel to the roadway (Fig. 7) and at right angles to the roadway (Fig. 8).

The time lapse for an outburst to manifest itself at West Cliff Colliery varies from several seconds to almost a minute, and is a comparatively slow movement of coal at the face. Coal becomes so soft that the machine head can penetrate the face. The outburst is associated with loosening of face and movement of coal from the face as a shear zone is approached. This gives warning for the machine driver to notice the movement (in the form of filling of the frontal areas of the face ahead of the machine) but not enough time to raise the winning head of the machine, switch off the power, and escape to the point of safety. This warning was evident even at the first occurrence, when the machine driver was not aware of this phenomenon and where almost 120 tonnes of coal were thrown out to a distance of about 7 m from the face.

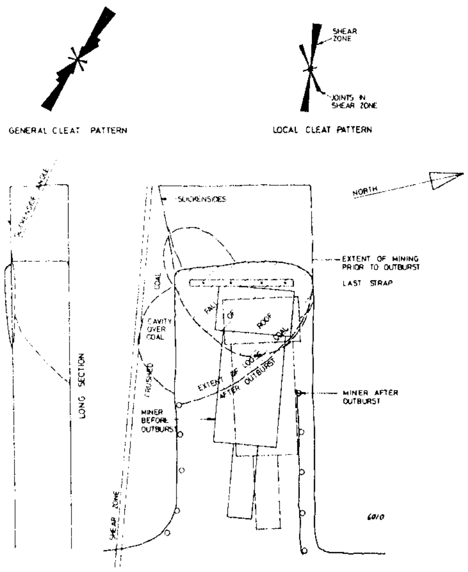


Fig. 7 - Outburst No. 3 West Cliff Colliery Bulli Seam. Drivage with shear zone parallel to roadway.

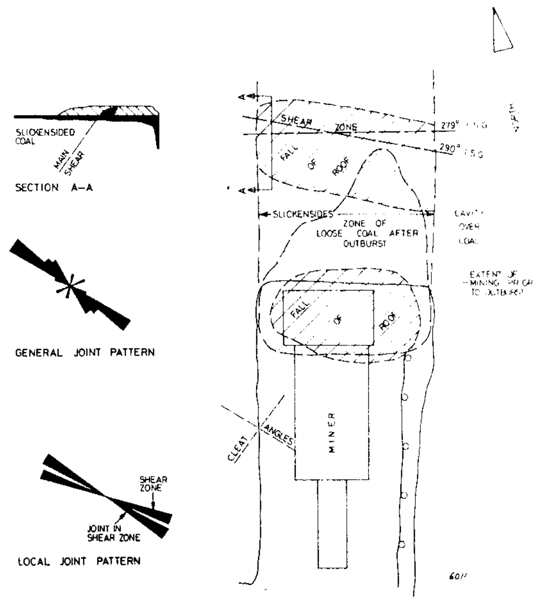


Fig. 8 - Outburst No. 1 West Cliff Colliery, Bulli Seam. Drivage with shear zone intersecting at right angles to the roadway.

The coal dislodged in the outburst comes mainly from the shear zone, with some large blocks detached from the surrounding part of the seam due both to movement of coal from the shear zone and as a result of lack of support in the comparatively large area exposed after an outburst. Fig. 9 shows some typical locations of outbursts, with associated features. These figures show that the amount of coal dislodged and the area affected by an outburst are not limited by the width of the shear zone itself, but are very much related to the presence of swarms of joints associated with the shear zone. (Fig. 9, (b), (c) and (d)) and the angle which the axis of the drivage makes with the shear zone. The flatter arm of the dislodged coal runs more or less parallel to the shear zone and is influenced by the parallel joints (Fig. 9(a)). Figs. 9(b) and 9(d) also show that the minimum width of coal between the face and the shear zone for the outburst to occur is about 2-5 m. As long as this distance can be maintained from the shear zone to the excavation edge, the danger of an outburst precipitating would be minimal. This is borne out by observations at several other locations. This figure agrees with other observations that the zone of fracturing is about 2 m ahead of the face. However, the zone disturbed along the shear zone may be much deeper and visual estimation showed that it could extend to beyond 10 m.

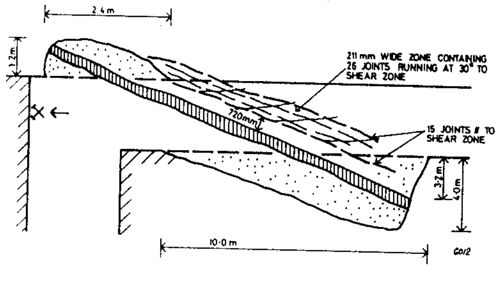


Fig. 9(a) - Some examples of outbursts and associated failures. Outburst No.85

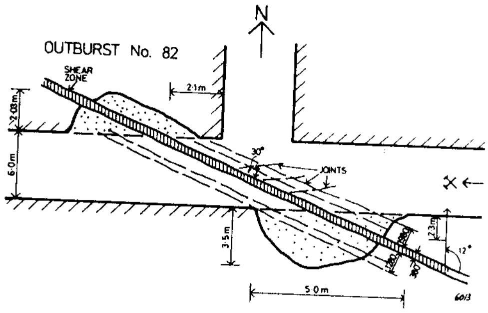


Fig. 9(b) - Some examples of outbursts and associated failures.Outburst No.82

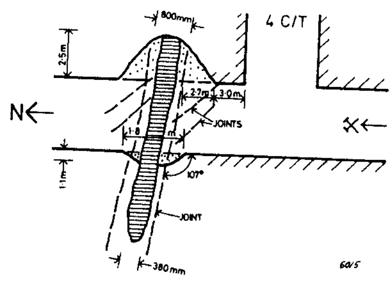


Fig. 9(c) - Some examples of outbursts and associated failures.Outburst No.26

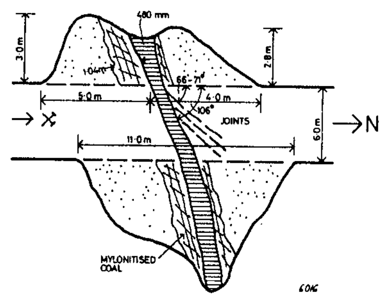


Fig. 9(d) - Some examples of outbursts and associated failures.Outburst No.20

Figs. 10 - 12 show some typical outbursts where the depth of penetration as seen along the shear zone can be estimated. The coal thrown out in an outburst is highly pulverised, having a silky touch, which is an indication of the extensive grinding to which it has been subjected. Within the shear zone there is ample evidence of both vertical movement and large horizontal movement (Fig. 13). The material, though pulverised, shows compaction - indicating that shearing has occurred under high stress normal to the shear plane.

Fig. 11 - Outburst No.94, West Cliff Colliery, Panel 211 14 cut-through west face

Fig. 10 - Outburst No.94, West Cliff Colliery, Panel 211 in cut-through, east face

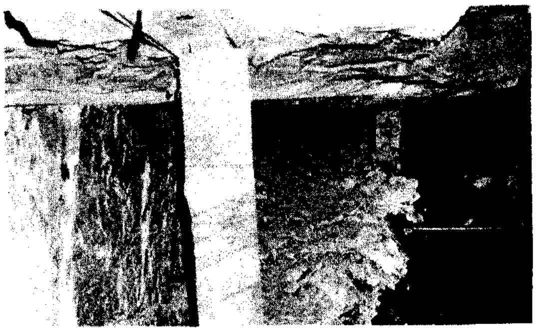


Fig. 12 - Outburst No.96, West Cliff Colliery, Panel 211, 15 cut-through west face

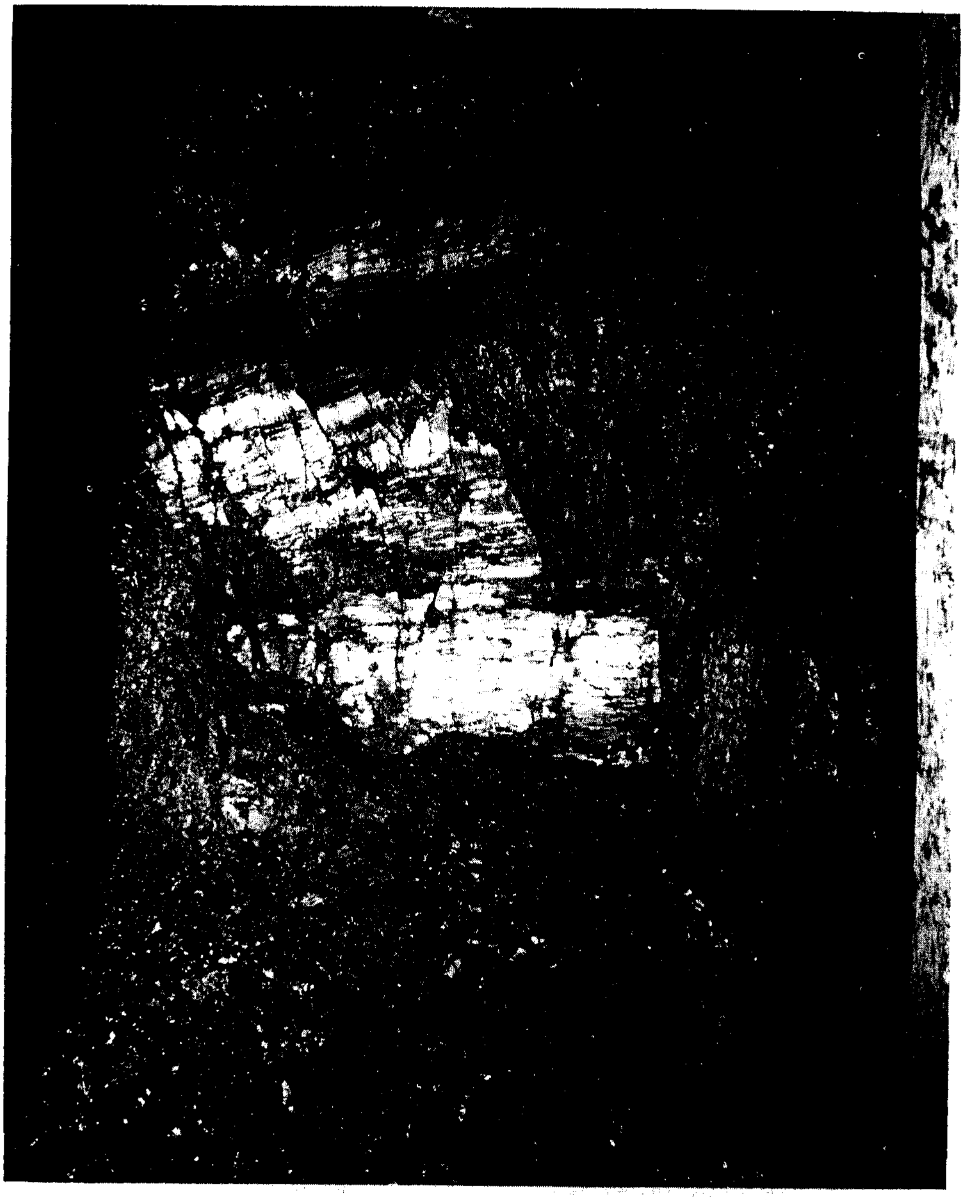


Fig. 13 - Outburst coal showing intensive horizontal movement in coal, West Cliff Colliery

Formation of haze has been reported during outbursting, which is an indication of drop in temperature. The formation of haze can be due either to increased humidity of air in the region of the outburst or to drop in temperature as a result of sudden liberation of gas at the face. Normal humidity at the face is about 90% at 20°C. Haze formation could take place if the temperature drops by 1.2°C. This drop in temperature would normally be noticeable but, in fact, warming of the atmosphere has been reported by the miners in a number of cases. The inseam gas temperature close to face is 22°C. It is therefore obvious that the occurrence of haze is due to the release of a large quantity of saturated gas into mine atmosphere, raising the ambient temperature, but simultaneously lowering the seam gas temperature. Since seam gas is saturated, slight lowering of its temperature would result in haze on the face. However, due to fracturing and comminution of coal, a small amount of heat would be generated, but this would not be significant. Drop in temperature of saturated seam gas is sufficient to cause water condessation and haze.

ZONE OF DESTRESSING DUE TO OUTBURSTING

When a roadway was being driven with the shear zone passing through the middle of the roadway and running ahead of it (Panel 304, heading J, outbursts 50, 51, 60, 63) (Fig. 1) the distance between successive occurrences of outbursts was about 15 m. This 60 m of roadway was driven over a period of 10 days. Similarly, in heading H (Panel 304, outburst locations 3, 4, 35, 38, 39) five outbursts occurred over a distance of 160 m. The span of 13 days could not relieve the gas pressure in the shear zone (outbursts 3 and 4) to a distance of 40 m. In another case the maximum time elapsed was 120 days between two successive outbursts (outbursts 21 and 35) with the shear zone running in the centre of the heading, and the distance between these outbursts was only 38 m. Two outbursts occurred on the same day, within five hours of each other, and on the same face (6 m wide), indicating slow release of gas pressure (outbursts 13 and 14, Panel 302, 3 June 1977) (Fig. 2).

Fig. 14 gives the relationship between the time elapsed and the spacing between outburst occurrences for the two cases. There is obviously no correlation between the time elapsed and the outburst interval.

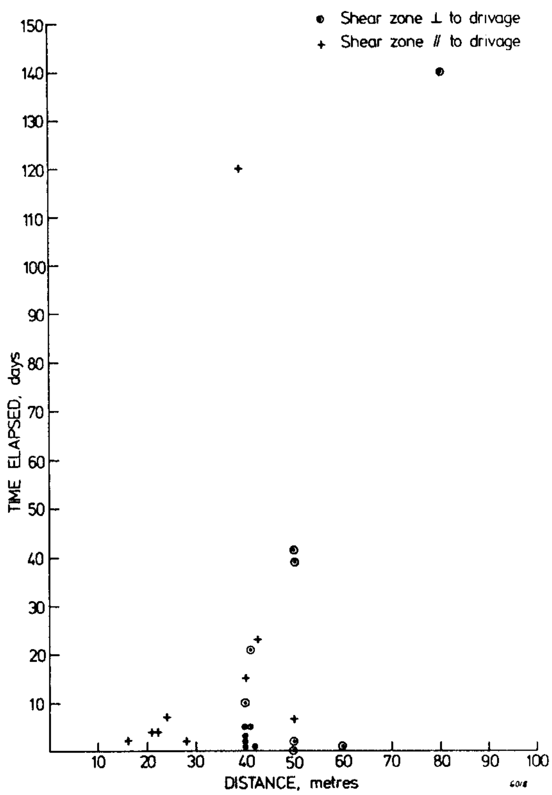


Fig. 14 - Relationship between distance between outbursts and time elapsed. ⊖ = shear zone at 90° to drivage; + = shear zone parallel to drivage.

The question naturally arises as why a period of 120 days was not sufficient to drop pressure to a distance of 38 m in the shear zone while in another case a period of 24 hours which elapsed between drilling of advance holes relieved the pressure in the shear zone and also influenced violence in the neighbouring heading 30 m away. It is only possible when the stresses acting at right angles to the shear zone are so high that they make the shear zone highly impervious. This also depends upon the direction of drivage with respect to the alignment of the shear zone. Fig. 15 illustrates the effects when a shear zone is intersected with a heading driven parallel and at right angles to it. The horizontal stress on the shear zone close to the face would be about three times greater when the shear zone is at right angles to the face than when it is parallel.

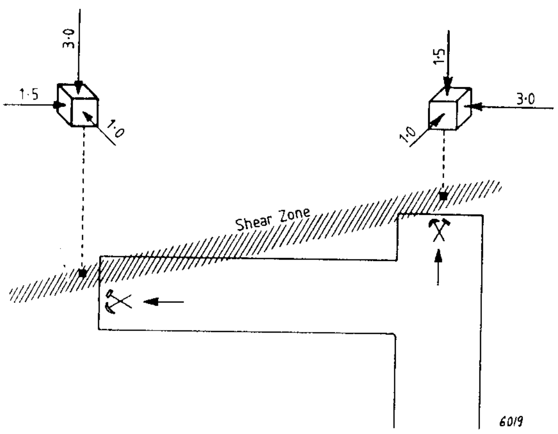


Fig. 15 - Stresses on a shear zone ahead of a face in relation to the direction of drivage.

The influence of high horizontal stress would mean that the coal ahead of the face would be subject to high horizontal stresses and the permeability of the coal would be greatly reduced. The zone relieved of stresses normally extends to about 2 m ahead of the face and the zone between 3 - 4 would be under high stresses (lateral front abutment). This means that degassing only takes place within 4 m of the face. Thus the shear zone, which forms the focus of outbursts at West Cliff Colliery, will maintain high pressure for a long period of time. Attempts were unsuccessful to relieve pressure using short holes of 43 m diameter in Panel 301. When the mylonite zone was flushed, it was too hard and too tight to be flushed beyond 4 m depth, indicating that the front abutment lies about 4 m from the face. This agrees very closely with a number of observations on outburst sites.

Samples of the coal were taken from the shear zone and compressed to 40 MPa (about 3 times the expected vertical stress). Permeability of these samples was up to 1.0 millidarcy at stress. This permeability is quite high, and as a result could not permit maintenance of higher pressure on its own. The influence of stress on the permeability of sheared coal is enormous (Fig. 16). This confirms that stress is the dominating factor on the severity of outbursts experienced when driving parallel to shear zones.

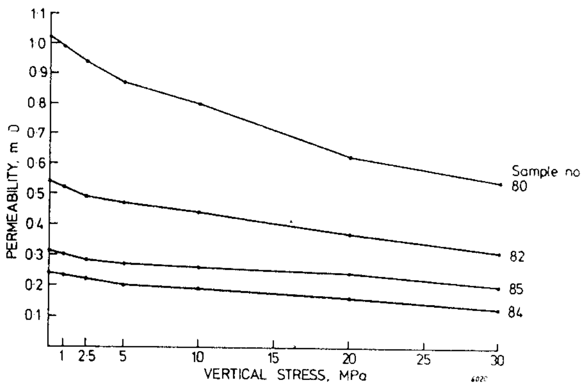


Fig. 16 - Influence of vertical stress on the permeability of sheared zone coal.

APPROACHES TO PREDICTION AND CONTROL OF OUTBURSTS

A number of approaches have been and are being developed to control outbursts and to minimise their effects. These include:

1) advance drilling
2) geological and structural approach
3) microseismic monitoring
4) adsorption/desorption techniques
5) advance drainage of gas

1. ADVANCE DRILLING

Advance drilling was the first method adopted to control outbursts. 100 mm diameter holes were drilled in advance of the headings to intersect the shear zones and release the pressure. Usually three holes were drilled at 2 m intervals on the face (Fig. 17). In H heading, 27 m long advance holes were drilled to intersect the shear zone (Fig. 17). Violent ejections of powder coal were experienced at intervals of approximately 10 minutes for almost 24 hours, with a mixture of pulverised coal and water (pulp) thrown out to 20 m (in one case 40 m) from the face. This indicates that the pulp velocity exceeded 3.3 m/s and the pressure in the borehole could be as high as 3200 kPa. This value agrees with pressure measurements conducted in the Colliery.

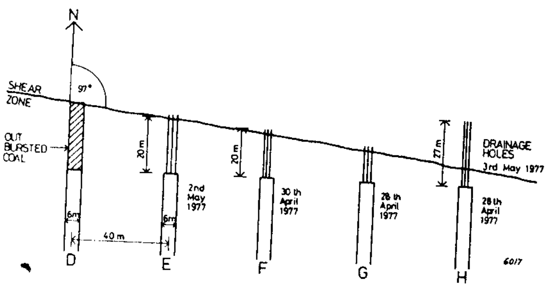


Fig. 17 - Drilling of 100 mm diam. relief holes in headings.

The intensity of these violent ejections decreased with time and was lower in heading G (Fig. 17), still lower in heading F, and almost non-existent in heading E. A period of 129 days had elapsed between the occurrence of an outburst in D heading and the drilling of these relief holes. In G heading where holes were drilled 24 hours after drilling holes in H heading, only two violent ejections of pulp occurred. In F heading, holes were drilled after 40 hours and no ejections occurred. Driving of roadways through the mylonitised shear zone in H heading after 170 hours produced no violent outbursts, but only slumping of loose coal.

This exercise proved that when shear zones are drilled through sufficiently ahead of the face and given enough time, they can be successfully drained.

2. GEOLOGICAL AND STRUCTURAL APPROACH

Shear zones which form foci of outbursts are continuous and extend sometimes for large distances. Location of these shear zones ahead of the faces can be projected and some success has been obtained in locating them. However, over long distances, these shear zones do not follow a straight line but deviate from their direction. From the centre of the property they seem to turn anticlockwise as one moves to the west of the Colliery holding. Holes up to 100 m long have been drilled to locate these shear zones in advance. Once the location of the shear zones is known, appropriate steps can be taken to minimise the effects of an impending outburst. In areas close to the shear zone, there is a tendency for coal to change its colour, reflectivity, and strength. On approaching a shear zone reddening of roof and coal occurs (the cuttings from drill holes also indicate this), and coal becomes softer and finer. These changes can be picked up by experienced miners and the colliery has had success in using these indices to predict an imminent outburst.

Investigations conducted by Dr. J. Shepherd, CSIRO (1979) show that joint frequency in coal increases with the approach of shear zones (Fig. 18). This technique is rather difficult to use successfully, but quite rapid changes in jointing close to a shear zone can give some indication to the miner of possible changes in the structure of the coal and the possible presence of outbursts. Sometimes it is too late, however, to detect these changes.

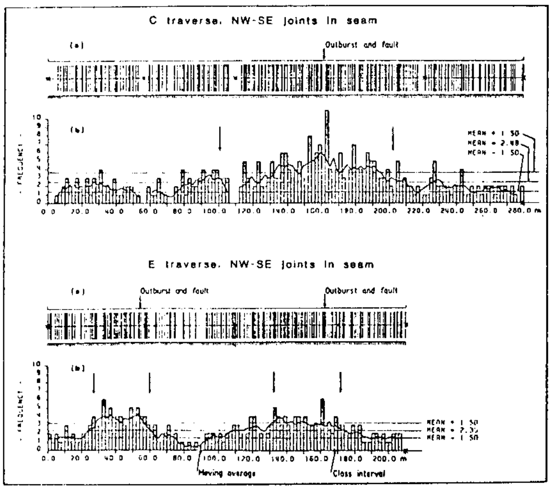


Fig. 18 - Frequency distribution of joints in coal on approaching an outburst site (Shepherd and Creasy, 1979).

3. MICROSEISMIC MONITORING

CSIRO has investigated the use of the microseismic technique to predict imminent outbursts at the face (McKavanagh, et al., 1979). The method consists of mounting a detector in the seam close to the working face and recording the microseismic noise after filtering out mining noise. The number of seismic events (number of counts) above a certain threshold is recorded. Records show a sustained increase in the rate of microseismic activity followed by a fall immediately preceding an outburst (Fig. 19). Changes in percentage of methane in the return have also been measured at the face immediately before an outburst occurs and these are in accordance with observations made as early as 1966 in the U.K.

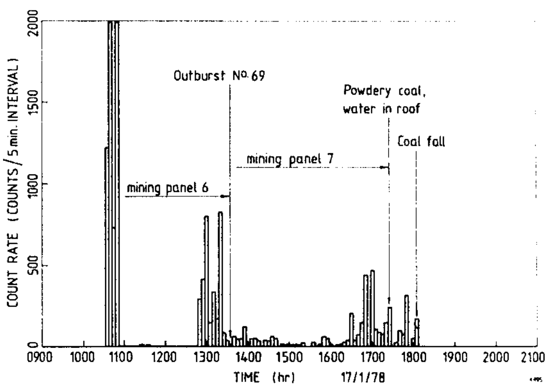


Fig. 19 - Count rate at test site No.2, 17/01/78, West Cliff Colliery, threshold level + 7.5 mV (McKavanagh et al., 1979).

A more refined system has been developed lately by CSIRO, which can be mounted on a continuous miner (Fig. 20). The miner driver will be able to listen to the microseismic noise through a headphone and both the working of the miner and the microseismic noise can be recorded on a magnetic tape for analysis. If this system succeeds, it is hoped that an on-site warning system can be developed to predict imminent outbursts.

4. ADSORPTION/DESORPTION TECHNIQUES

A number of methods using adsorption/desorption techniques have been tried to predict imminent outburst conditions. Of the established methods, the most common indices used are ΔP, ΔV, ΔPexpress and k value (Lama, 1980). Tests have shown that though ΔP express and K value methods cannot differentiate between outbursting and non-outbursting coals from different areas of the colliery and their use as a predictive tool in West Cliff situations is extremely limited, if not invalid. Two new indicators L_1 and L_2 have been developed (Lama, 1980). The L_1 index is based upon long term adsorption of gas from coal and the L_2 index is based upon desorption of gas from coal. The L_1 index seems to be a quick way of differentiating major changes between different zones where outburst proneness of coal may change. The L_2 index shows promise as a practical means of indicating not only an outburst condition, but also changes in the structural properties of coal, and predicting in advance (from 10 - 15 m) an approaching shear zone. It is hoped that the use of this method would give enough warning of an approaching outburst. However, it is still in the laboratory stage and equipment has to be developed for its use under mining conditions. More details are given in an other paper by Lama presented in this symposium.

5. ADVANCE DRAINAGE OF GAS

One of the most effective and economical techniques can be drainage of gas from the solid in advance of development headings. A comprehensive field and laboratory programme of investigations has been carried out to investigate the feasibility of drainage of shear zones and stressed solid coal of the Bulli Seam at West Cliff colliery. The various parameters that have been investigated include;

- gas pressure *in situ*
- gas flows from boreholes
- productive life of boreholes and effective drainage time
- optimum spacing of boreholes for effective drainage

Studies have shown that gas pressures greater than 3000 kPa may be present in Bulli Seam. Flow rates from boreholes vary. On the average one could expect about two litres per minute per metre length from a 50 mm diameter hole. Where shear zones have been intersected, flow rates of the order of 10-20 litres per minute per metre of borehole have been measured. Fig. 21 shows drainage hole installations underground.

Investigations have shown that the sphere of influence of a drainage hole in Bulli Seam could extend to 30 m radius, but due to a limited lead time available, drainage boreholes so far have been placed at spacings of 10-18 m.

A full-scale drainage system has been installed at West Cliff Colliery. It became operational on 1 March 1980. This is the first successful methane gas drainage scheme in Australia. More details are given in the paper by Lama et al. presented in this symposium.

CODE OF PRECAUTIONS ON APPROACHING AN OUTBURST

During mining when a shear zone is expected to be intersected or an outburst is imminent, special precautions are needed to drive the headings safely. Based upon experience, a code of precautions has been developed. The various points to be taken into consideration are as follows.

1. Deputies' plans shall clearly indicate potential outburst zones determined from the most recent information available.
2. When mining near a known potential outburst zone, the maximum number of men at the face at any one time shall be four (4).

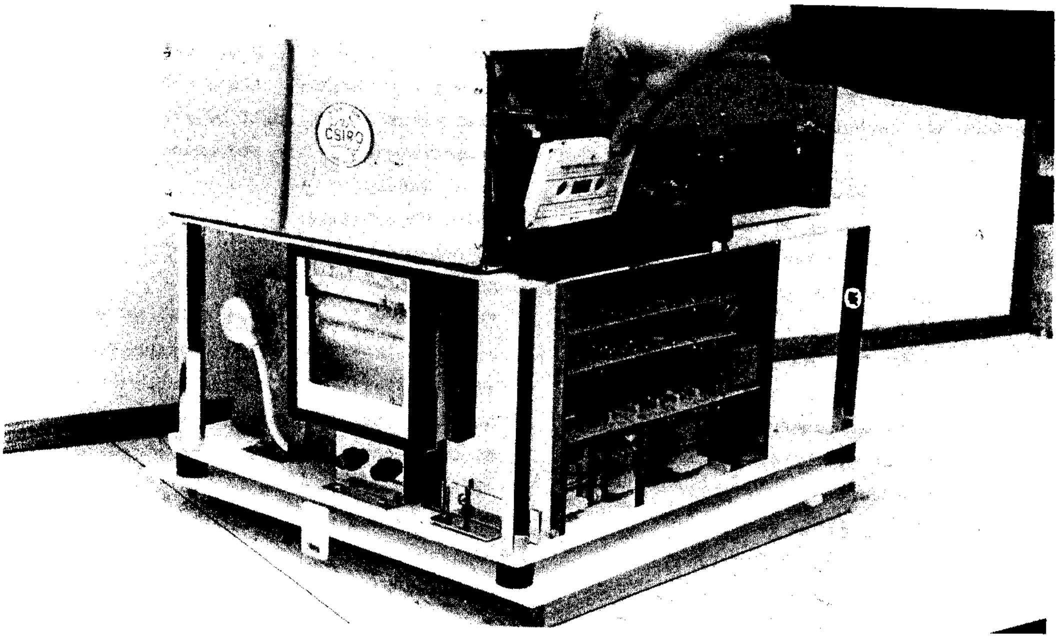


Fig. 20 - Continuous miner mounted single channel microseismic system

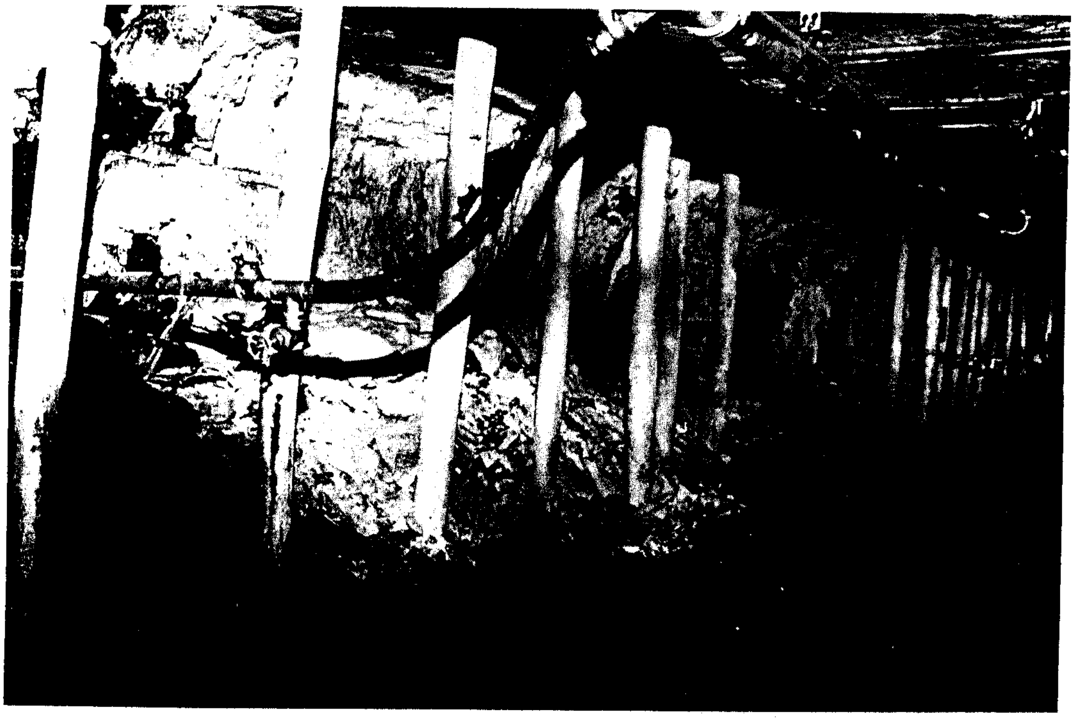


Fig. 21.- Holes for drainage of gas from the solid, Bulli Seam, West Cliff Colliery.

3. Four-man crews experienced in mining through outburst zones shall be used to approach all outburst or potential outburst zones.
4. When approaching a known potential outburst zone continuous miner operators shall not undercut the face. The sequence of cutting the face shall be from roof to floor.
5. If signs indicate that an outburst zone is imminent, e.g. softening of the coal, increase and/or fluctuations in gas yield, change in frequency and/or direction of joint systems, stretch marks in roof, the power to the miner shall be switched off at the gate end box and the face area thoroughly stonedusted. Power may then be restored and careful mining commenced.
6. The standard of ventilation (both face brattice lines and earthed venturi) shall be kept high at all times. Regular checks shall be made with respect to air quantities and gas percentages both at the face and behind the brattice, especially during the mining cycle.
7. Any outburst prediction equipment in use at the time shall be kept in proper working order and checked regularly for efficient operation.
8. If an outburst occurs, all electric power to face machines shall be switched off at the gate end boxes and employees shall retire without panic to a safe location as determined by the Deputy. No one shall re-enter the face until it has been inspected and declared safe by the Deputy or superior official.
9. After each outburst, all details shall be recorded on the outburst record sheet by the Deputy, face crew and superior officials. After completion, this record sheet shall be read and countersigned by the following persons:
   Panel Deputy
   Shift Undermanager
   Undermanager-in-Charge
   Mine Manager
   This countersigned sheet shall be passed on to the Chief Surveyor who shall arrange plotting of the outburst zone on the outburst plan and formal filing of the record. A copy of this record shall be forwarded to the District Inspector and posted on the surface noticeboard.
10. Outburst record sheets (Appendix 1) shall be made available in the surface G.R.4 Station. It is preferable to complete as much as possible of the outburst record sheet underground immediately after the outburst.

This Code also sets down details pertaining to:

1) Composition of the Joint Advisory Committee, which is responsible for reviewing and amending the Code in the light of experience.
2) Communications.
3) Safety equipment, including availability of compressed air in the driver's compartment and fitting of a protective screen on each continuous miner.
4) Availability of self-contained breathing apparatus in each panel.
5) Training of all underground employees with respect to outbursts and use of safety equipment.

CONCLUSIONS

Experience of outbursts at West Cliff Colliery has indicated that these are associated only where coal has already been pulverised in shear zones running through coal. These shear zones are also regions of high gas pressure when intersected immediately, and this results in displacements of a larger amount of pulverised coal into the excavations. A number of studies have been undertaken to predict and control outbursts and these include determination of the shear zone by advance drilling, geological and structural approaches and microseismic and adsorption/desorption monitoring. Advance drainage of gas seems to be most promising. A full-scale gas drainage plant has been established at the Colliery and it is hoped that extensive gas drainage will ultimately eliminate outbursts.

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APPENDIX 1

West Cliff Mine - Outburst Record

Subject	Comments
1. Reference No.	
2. Date	
3. Time	
4. Location (with sketch)	
5. No. of shuttle cars filled	
6. Activity before burst: (a) audible warning (b) other (specify)	
7. Changes in coal properties before burst: (a) hardness (b) colour	

APPENDIX 1 (Cont.)

(c) moisture	
(d) other (specify)	
8. Changes in geological features before burst:	
(a) roof jointing	
(b) coal jointing	
(c) stress indications	
(d) other (specify)	
9. Return air gas analysis:	
(a) before burst	CH_4 .... CO_2 .... CO .... O_2 ......
(b) after burst	CH_4 .... CO_2 .... CO .... O_2 ......
(c) any increase in gas pressure/ emission	
(d) any sample taken after burst (sample No.)	
10. Air quantity in panel	
11. Position on face where burst started	
12. Intensity of burst: (movement of face equipment)	
Distance to which coal is thrown	
13. Duration of burst, minutes, seconds	
14. Nature of coal that was burst, fraction sizes, largest particle size, sample taken (sample No.)	
15. Activity immediately after burst:	
(a) temperature rise	
(b) smell	
(c) haze	
(d) other (specify)	
16. Direction of drivage	
17. Distance from burst face to mylonite zone	
18. Change in:	
(a) seam thickness	
(b) gradient	

APPENDIX 1 (Cont.)

19. Shape of resulting burst cavity	
20. Microseismic details (if employed)	
(a) highest 5 minute average count within 1 hour before burst	
(b) period of increased activity	
(c) period of warning	
(d) position of detector	
(e) detector mounting technique	
21. Other relevant comments:	