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A Review of Fatal Outburst Incidents in the Bulli Seam

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ABSTRACT

The Bulli Coal Seam, located in the Illawarra Coalfield of New South Wales, has a long and varied history of sudden outbursts. From available information this problem has resulted in twelve fatalities over the last one hundred and one years, with over five hundred separate outburst incidents being identified. These incidents have varied in severity and intensity from the discharge of 1 to 2 tonne of coal, with a slight increase in gas emission, to the discharge of 200 to 400 tonne of coal with some 6,000 m^3 of gas being liberated and large items of mining equipment being pushed 1 to 2 metres down the roadway.

Geological features associated with these outbursts can be mapped on a regional and mine by mine basis, to provide some indication or warning. Similarly changes in gas content and gas composition can also be determined on a regional and mine by mine basis. However sudden geological changes (such as a 6.5 metre seam displacement within 15 metres) variations in gas content (such as 6 m^3/tonne to 15 m^3/tonne) and changes in gas composition (from 95% CH_4 to 90% CO_2) all within one mine does make the prediction or forecasting of outburst incidents exceedingly difficult.

A review of the fatal outburst incidents in the Bulli seam can give valuable insight into how efficient coal mining, within the Bulli coal seam is now linked with the effective use of gas drainage techniques and the management of the outburst risk. The number of variables and "unknowns" associated with outbursts have required the development of fully documented procedures and systems, so that at all stages during the mining operation the risk of injury to mine workers is minimised. The main emphasis for these management systems is the prevention of outbursts by relieving gas pressures using drainage techniques to achieve specified threshold gas level to permit safe mining conditions.

INTRODUCTION

The Bulli coal seam as a primary source of coking coal is a major economic resource for New South Wales and Australia. Geological conditions associated with this seam have required the development of specialised mining techniques and the adaptation of mining equipment, for coal mines to remain competitive. For many years outbursts have been regarded as a mining phenomena one of the many quirks of nature which make underground coal mining inherently dangerous. Today this type of approach is unacceptable.

The challenge to modern day mine management is to recognise the problem; research and understand it; then develop mining and management systems so that as much coal as possible can be mined as safely as possible. A detailed review of the fatal outburst incidents for the Bulli seam, will show how the level of knowledge and understanding of outbursts have evolved and, how plans and systems have been developed to effectively manage the outburst risk.

BULLI SEAM OUTBURSTS

Whilst outbursts have been a phenomena associated with mining the Bulli coal seam for the last one hundred and one years, the mechanism behind outbursts was not fully understood and hence the various outburst parameters were not

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clearly defined. This lack of definition and background information was due mainly to each mine being responsible for its own operations, as well as an inability to admit that outbursts were a problem for all Bulli seam mines. As a consequence, a lack of technology and information transfer between mines existed for some time.

This situation changed drastically after the South Bulli Outburst, 25 July 1991 when three miners were killed. Various working groups and task groups were established to identify the mechanisms causing outbursts, the most suitable means of managing the outburst risk, develop standardised data collection and information interchange within the industry, review outburst prediction techniques and recommend areas of future research. The general characteristics of outbursts as they relate to Bulli seam mines are given in Table 1. The importance of structures, seam gas composition and seam gas concentration are apparent. Similarly gas drainage was identified as currently the only effective mechanism for preventing outbursts.

Table 1 – Bulli seam outbursts

Colliery	No. of Outbursts	Size in tonnes	Gas	Geological Structure
Appin	22	2 - 88	mainly CH_4 & CO_2 on dykes.	Predominantly strike slip faults; mylonite zones.
Brimstone	2	30	CO_2	Mainly dyke related structures with strike slip movement.
Corrimal (closed)	4	12	CH_4 & CO_2	Shear zone associated with minor faulting & dykes.
Kemira (closed)	2	60 - 100	CO_2	normal fault with mylonite.
Metropolitan	37	1 - 150	mainly $C0_2$ with minor amounts of CH_4	Predominantly with dykes & faults that exhibit slicken sides & mylonite.
South Bulli	7	1 - 300	mainly CO_2	Strike slip faults with mylonite; dyke zones & thrust faults.
Tahmoor	88	5 - 400	mainly CO_2	Mainly strike slip faults; with dykes (110° - 135°) & thrust faults: mylonite usually present.
Tower	19	1 - 80	mainly CH_4	Mainly strike slip faults with dykes.
West Cliff	250	4 - 350	mainly CH_4 with CO_2 to the NE development	Predominantly strike slip faults (100° - 110°) with slicken sides & mylonite; dykes and thrust faults have been associated with outbursts.

FATAL OUTBURST INCIDENTS

Up to December 1997 there have been twelve fatalities attributed to outbursts in the Bulli seam. These are summarised in Table 2 and discussed in detail below.

Table 2 - Fatal outbursts in the Bulli coal seam

COLLIERY	DATE	No. KILLED	SIZE (tonnes)	GAS	STRUCTURE
Metropolitan	10 June 1896	3	Unknown	CH_4 (firedamp)	Dyke and soft fault zone
Metropolitan	27 July 1926	2	140	CO_2	Fault with 5m throw
Metropolitan	2 December 1954	2	90	CO_2	Normal fault with 0.3m throw
Tahmoor	24 June 1985	1	400	CO_2	Behind a dyke associated with strike slip movement
South Bulli	25 July 1991	3	300	CO_2 & CH_4	Thrust fault with 35 cm of mylonitic coal; very high gas pressure.
West Cliff	25 January 1994	1	350	CO_2	Intersection of 2 strike slip structures; 30 cm of mylonitic coal.

The reports and documentation on the earlier incidents are sketchy and limited to the reports prepared and available at the time. Records from the Department of Mineral Resources have proven to be the most informative.

10 June 1896

On 10 June 1896, three men were killed by an outburst of coal and gas at Metropolitan Colliery (Enoch Pugh; James Borton and H. Shipton). The men were suffocated by the gas (claimed to be fire damp) from the outburst in the No. 7 West Heading. An inquest was held on 11th June 1896 at the Metropolitan Colliery Office by the District Coroner, C.C. Russell, Esq. The jury returned a verdict of accidental death.

27 July 1925

On 27th July 1925, two men were killed by an outburst of natural gas and coal at the Metropolitan Colliery (George West and Fredrick Green). The men were suffocated by the gas emitted (identified in 2 samples as being between 50% and 62% CO_2) from the outburst site and was associated with an upthrow fault immediately adjacent to a dyke in the 70 yard heading of the Western area section of the mine (see Figs 1 and 2). Approximately 220 tones of coal was ejected with the gas concentration being sufficient to kill a horse approximately 115 yards away from the outburst site.

Miners working the area had commented that the coal immediately prior to the outburst was harder than usual. It had been identified in previous outburst incidents that these events were related to geological structures, particularly dykes where the characteristics of the coal had been significantly altered, and fortunately these incidents had not been fatal. The concept of one district or part of the mine having outburst prone zones was recognised.

Hence the comments of the Inspector reporting on the fatality and the mechanisms used to alleviate outburst problems are quite telling: - "Since the outburst, boreholes have been kept ahead in all places in the near vicinity of the fault and these have given off a little gas which has proved to be practically pure carbon dioxide".

Similarly the mechanism underlying the principles behind outbursts in the Bulli Seam were alluded to when the same inspector commented "The last four feet or so of coal worked by the miners in this place was harder than usual, and no gas had been given off..." "This hard section of coal may have acted as a dam and retarded the escape of the gas which is given off freely from the coal faces in this section."

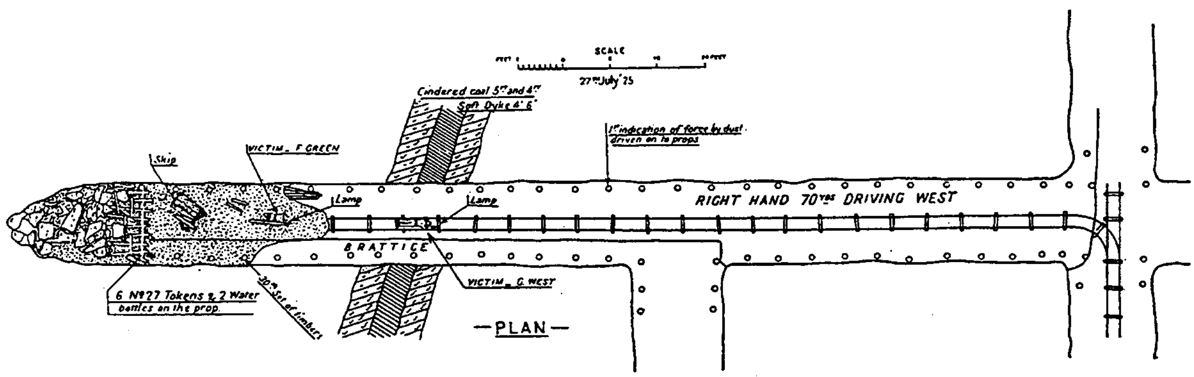

Fig. 1 - Scene of fatal accident to F Green and G West, outburst of gas Metropolitan colliery

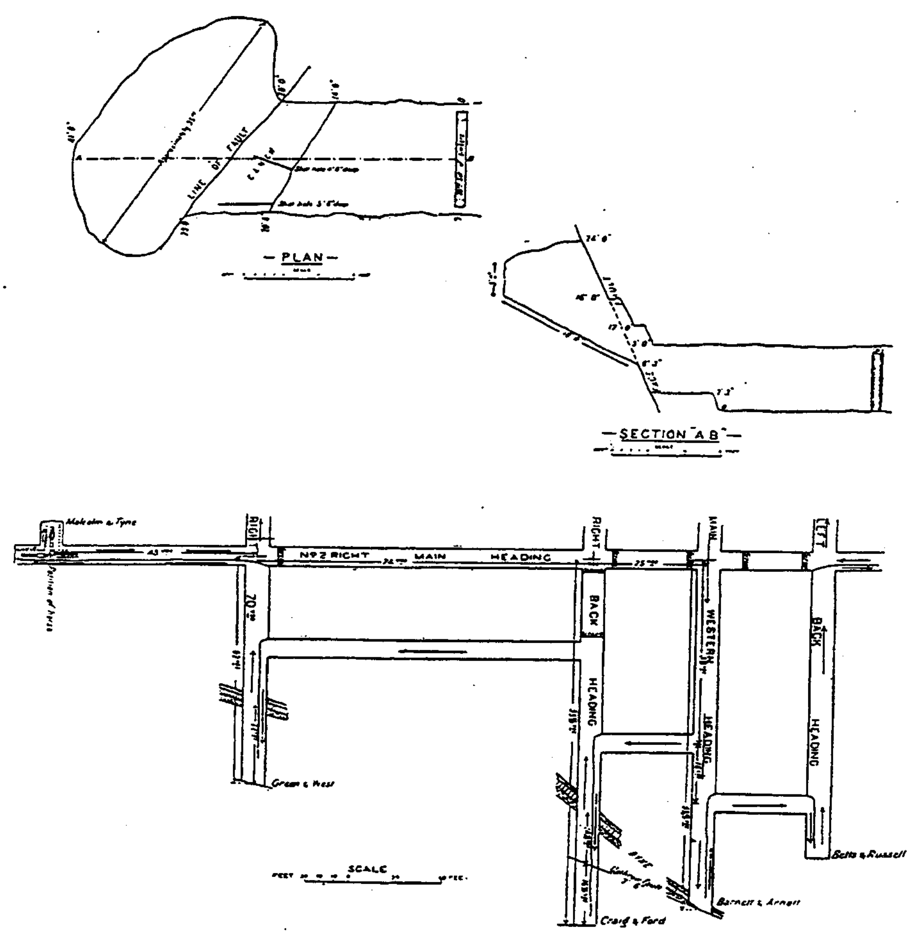

Fig. 2 - Outburst of Gas – Metropolitan Colliery

2 December 1954

On 2 December 1954; two men killed by an outburst of the Metropolitan Colliery. (names not given in Dept. Annual report): the men were asphyxiated by the gas (deduced to be CO_2) and a boring machine operator rendered unconscious.

The outburst was in an area of known faulting with the site being associated with two small down throw faults with several defined vertical joint planes in the shale roof and a well defined "slicken sides" in the seam, coal in the fault area was soft; and being worked under fully mechanised mining methods. The use of boreholes to identify outburst structures was raised in the Chief Inspector of Coal Mines report, stating:- "In my opinion, the recent happenings clearly indicate the necessity for maintaining the boreholes well in advance of all solid places and, in addition to the centre hole, flank holes are being bored in each rib and the holes are being maintained at least twenty five feet in advance of the faces".

24 June 1985

On 24 June 1985, one man (Michael Joseph Penny) was killed whilst operating a continuous mining machine in an outburst prone area (C heading of 204 panel) of Tahmoor Colliery. The outburst resulted in approximately 330 tonnes of coal and roof shale material and an estimated 3500 cubic metres of gas, comprised predominantly of carbon dioxide.

The outburst was associated with a known dyke structure which had been intersected in three previous panels with increasing thickness from 20 cm to 1m. The thickness of the outburst site could not be determined due to roof falls. In 204 panel, about four metres before the dyke an off shoot of an igneous intrusion (about 30m thick) was identified along with a shear zone and severe jointing being evident in the roof.

Due to previous outburst events and the proximity of the dyke the area to be mined was considered to be outburst prone. Hence outburst precautions were to be taken. The continuous miner was set up to cut out the right hand side of the heading with the head of the machine being sumped in at the roof.

At the time of the incident the shuttle car was behind the continuous miner and the driver sustained superficial facial injuries from small particles of coal and other material ejected by the outburst. Material ejected in the outburst covered the continuous mine the shuttle car, with the only access to the operators cabin on the continuous miner being via the rear of the canopy. The autopsy report indicated that the operator of the continuous mining machine died from asphyxiation. The other four men (including the shuttle car driver), recovered after making their way to fresh air.

An inquest into the event was held on 4 November 1985 before Coroner Donna Maria Delaney in the Campbelltown Coroner's Court. The finding was "died of asphyxiation due to the inhalation of coal gas from an outburst".

Consequent to this incident the following recommendations were given to enhance safety whilst mining in outburst prone areas of Tahmoor mine.

1. Upgrade the miner driver's cockpit to give the driver better protection as well as having an independent air supply.

2. Gas drainage is to be carried out to the satisfaction of the District Inspector of Coal Mines.

3. It is intended to require the manager to use pulsed infusion shot firing similar to a recent practice of Metropolitan Colliery, if the gas drainage results do not prove satisfactory.

4. Modified precautionary measures will be put into practice whilst mining through outburst prone areas.

24 July 1991

On 24 July 1991, three men (Craig John Broughton, Robert Kelvin Coltman and Leigh Ronald Pearce) were killed by the outburst of coal and gas at the South Bulli Colliery.

The outburst in "B" heading of W12 Panel ejected an estimated 300 tonnes of coal and 6000 m^3 of gas (predominantly CO_2) into the working area. This occurred with sufficient force to dislodge the ventilation ducting, losing the auxiliary fan ventilation, slew the shuttle car sideways and had sufficient force to blow open the outbye ventilation doors causing a short circuit in the ventilation. The continuous miner driver was buried to his neck with outburst material and it is believed he died instantaneously from the effects of carbon dioxide. The shuttle car was being driven away from the continuous miner at the time of the outburst and from the injuries sustained by the car driver it would appear he was thrown out of the driver's compartment by the force of the outburst. It would appear that the third miner killed, died attempting to assist the car driver and, was overcome by the gas.

Although the outburst had not been predicted, the investigation revealed that there were significant changes in face conditions with such factors as ingress of water, changes in stress direction, roof jointing, roof guttering, poor conditions, fluctuations in gas concentrations and gas composition. The presence of greasy backs, (slicken sides), white clayey material in the roof and softening of the coal were also observed. The inability to recognise and understand the significance of these changes ultimately lead to the death of these men.

25 January 1994

On 25 January 1994, one man was killed by an outburst of coal and carbon dioxide gas at West Cliff Colliery (Malcolm Leslie Butt). The outburst occurred in "B" heading of 486 Panel and ejected 260 tonnes of coal, with a large but unquantifiable amount of carbon dioxide from the right hand rib side.

On the previous shift, mining activity in the panel were operating under "normal" mining procedures (not outburst mining procedures). A number of changes in mining conditions were noted, particularly the hardness of the coal at the face, deterioration in roof conditions, the presence of a "greasy back" otherwise known as slicken sides in the roof trending longitudinally down the heading and, an increase in carbon dioxide being emitted during mining operations.
These changes in mining conditions were deemed to be of significance, causing mining to continue only under outburst mining procedures. It is believed that this decision prevented other people from being killed, injured or affected, as outburst mining procedures limited the number of people working in the vicinity of the face.

The continuous mining machine in use was equipped with a purpose designed and built outburst protection canopy, including a supply of filtered air for breathing, via a half face mask. However, even with this protection, the miner driver was killed in the outburst. A post mortem revealed that the miner driver had died of anoxia and had sustained a small linear fracture to the rear of the skull, believed to have been caused by direct impact with the filtered air supply regulator gauge, at the time of the outburst.

The coal ejected from the outburst entirely covered the continuous mining machine and back to a distance of thirty metres from the face. The carbon dioxide gas given off with the outburst was in sufficient quantity to entirely fill the face area, displace all oxygen and proceed to migrate back down the panel, filling number seven cut through and affecting the adjacent heading.

As shown in Figs 3, 4 and 5, the outburst was associated with a combination of two strike slip fault zones (one trending 350°, the other 280° magnetic). The intersection of these two fault structures created a zone of intense shearing/jointing resulting in lower coal permeability and increased stress in the coal and associated roof strata. This in combination with the presence of Mylonite and gouge material was believed to account for the volume of gas released.

The dominant 350° fault zone appeared to have a similar alignment with strike slip fault structures identified in previous mining, associated with development headings for panels 484 and 485. Drilling immediately in advance of mining, in "B" heading of 486 panel did not accurately identify the location of this structure. Gas drainage holes drilled from 485 panel failed to reach across the longwall block and effectively drain the development heading of 486 panel. Also whilst holes had been drilled in advance of mining in 486 panel, they had not penetrated the structure. These holes had deviated to the left (south) and were identified in the left hand rib and face.

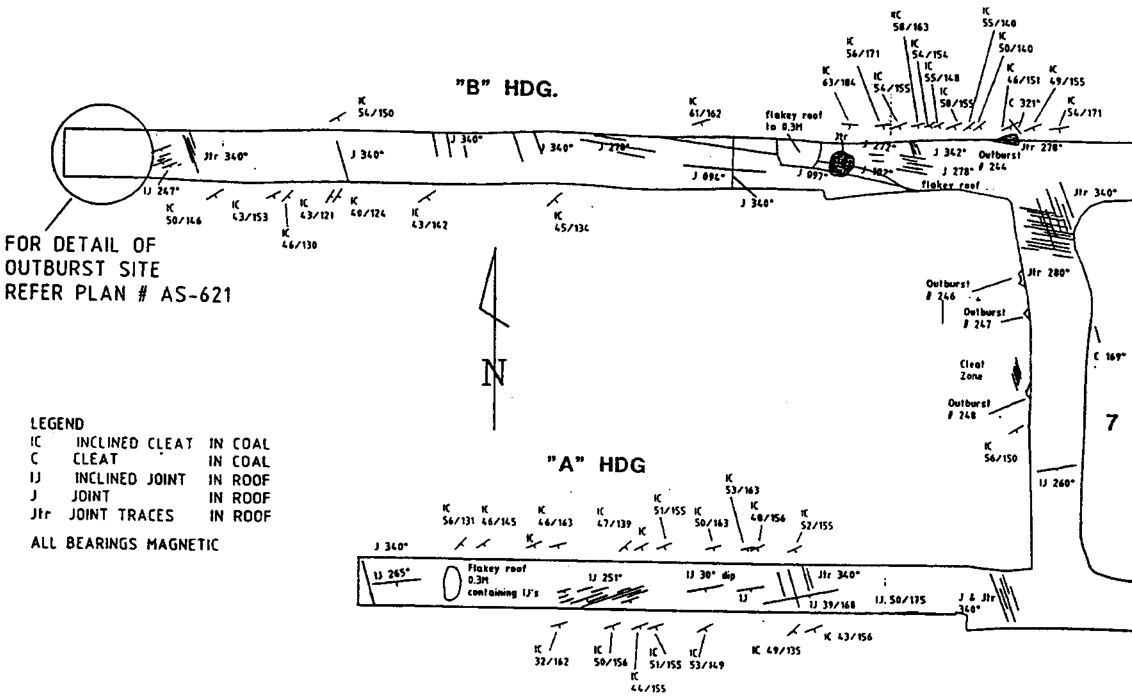

Fig. 3 - West Cliff Colliery 486 right panel outburst and fatal accident geological mapping

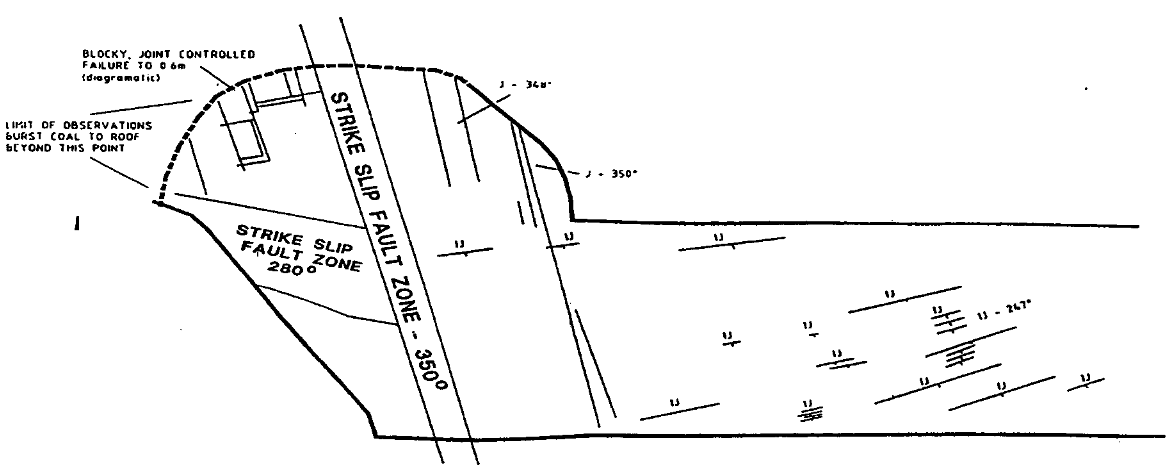

Fig. 4 - West Cliff Colliery 486 right panel outburst and fatal accident site geology plan

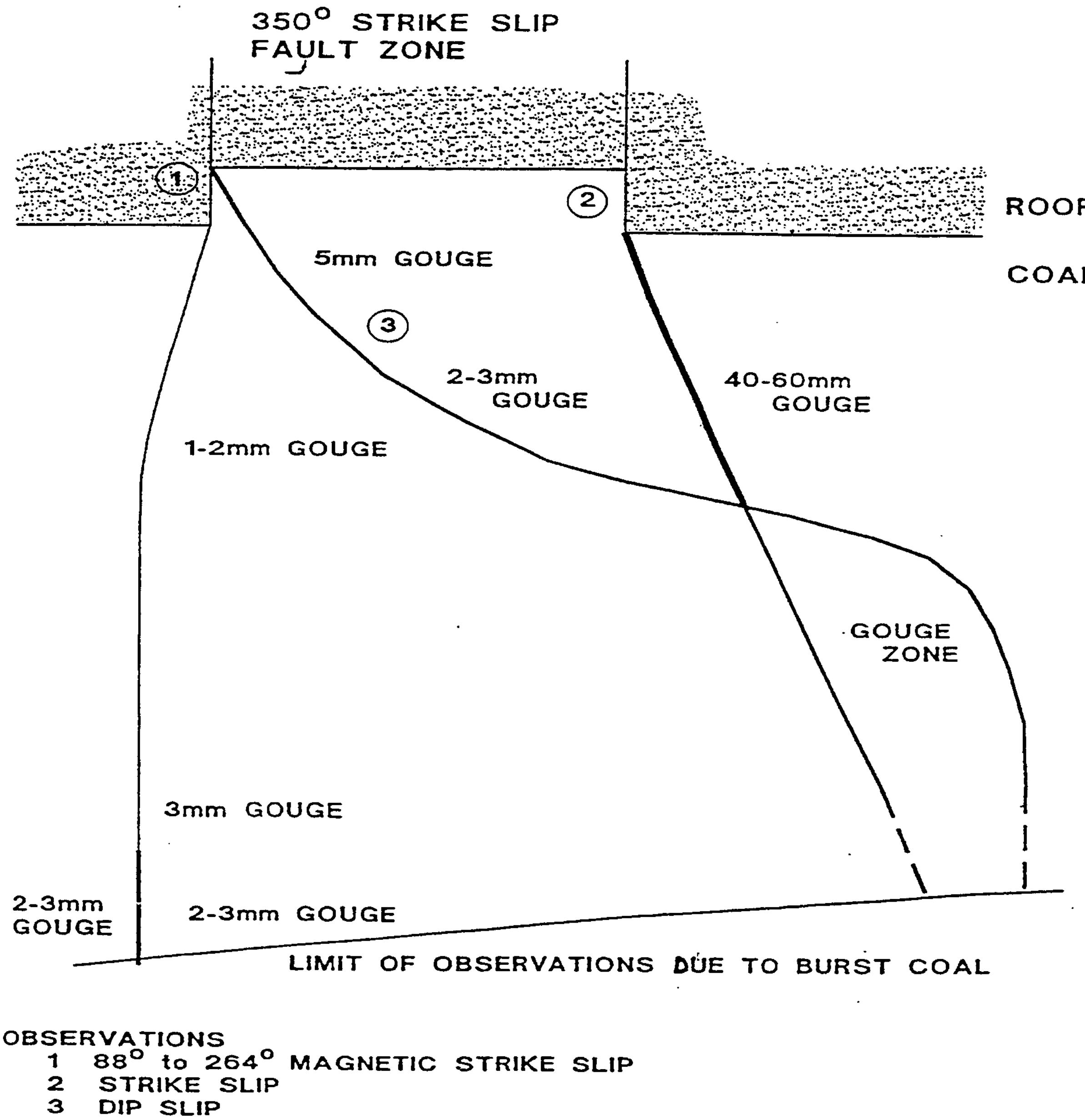

Fig. 5 - West Cliff Colliery 286 right panel outburst and fatal accident section through strike slip fault "b" heading southern rib

WHERE TO NOW ?

Since 1994 an order under Section 63 of the Coal Mines Regulation Act (1982) has been imposed on all mines operating in the Bulli Coal Seam. This order sets rigorous levels for insitu gas concentrations (being 9 m^3/t for CH_4 and 5 m^3/t for CO_2) for mining to be permitted.

Consequently outburst mining procedures are now regarded as an ultimate barrier which should not have to be utilised. The concept of sealing a continuous miner driver in a special canopy while more then two hundred tonnes of coal is ejected at him, in an irrespirable atmosphere, no longer has a great deal of appeal. Hence gas drainage now has a greater level of significance for all Bulli seam mines.

The refinement of gas drainage techniques have seen the development of specific drainage profiles for different gas concentrations, focusing upon the spacing of drainage holes and the amount of time necessary to achieve the threshold values, thereby permitting safe mining operations. In conjunction with these advances in gas drainage methods there have been significant improvements in drilling techniques and technologies, focusing upon the need for directional drilling control and surveying of the holes.

The overall management of all the components and information needed to verify that it is "safe to mine" has been encapsulated in outburst management plans. In this respect an outburst management plan (OMP) is a control document which specifies practices, resources, activities and responsibilities relevant to the effective management of the outburst risk. To achieve this and effectively manage the outburst risk the management plan should have the following elements:-

- The OMP must be based on an assessment of the outburst risk to be managed at each particular mine site. Due regard must be paid to the different levels and types of risk presented by predominantly carbon dioxide as opposed to methane seam gas environments.

- The OMP must be fully and effectively documented to ensure that processes and standards at the mine are suitable for the management of the outburst risk and proceed in accordance with the plan.

- The OMP must contain a policy statement signed by the most senior officer of the mining company.

- The policy statement should contain an expression of the broad objectives of the plan and the corporation's commitment to the attainment of these objectives.

- The OMP must ensure that all documents and records are maintained to indicate that all appropriate actions have been taken.

- The OMP must be in a form which allows effective transfer of information and responsibilities, which is able to be effectively updated. And

- The OMP must be adequately resourced in respect of plan development, implementation and ongoing maintenance. This will include the appropriate involvement of employees.

To facilitate the preparation of these plans the Department of Mineral Resources has prepared an Outburst Mining Guideline; MDG No: 1004, outlining the essential elements and components for an effective Outburst Management Plan.

CONCLUSIONS

The level of knowledge and understanding in managing the risk of outbursts for Bulli seam mines has definitely improved. One hundred and one years ago outbursts were regarded as an inevitable risk of mining and to some extent were treated as an "act of god". Currently gas drainage is utilised as the primary mechanism for taking the energy out of an outburst structure and thereby making it safe to mine. The Outburst Management Plan is the mechanism whereby assurance is given that all precautions are in place, gas drainage has achieved the appropriate threshold levels and it is in fact safe to mine.

The success in managing the outburst risk has the potential to generate complacency and for this reason attention must be directed to auditing the outburst management plans and improving gas drainage techniques. It is possible that guidance for the future may come from past observations particularly the comments of the Inspector reporting on the 1925 fatality; "Since the outburst, boreholes have been kept ahead in all places in the near vicinity of the fault, and these have given off a little gas which has proven on analysis to be practically pure carbon dioxide."

Also the comments from the Chief Inspector of Coal Mines reporting on the 1954 fatality; "In my opinion, the recent happenings clearly indicate the necessity for maintaining the boreholes well in advance of all solid places and, in addition to the centre hole, flank holes are being bored in each rib and the holes are being maintained at least twenty five feet in advance of the faces". Gas Drainage would appear to be part of the answer there may be the limitation to this technology

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