Department of Industry
Resources Regulator

Mine Safety

MINE SAFETY INSPECTORATE

INVESTIGATION INFORMATION RELEASE

High potential incident

Incident date	19 August 2016
Event	Coalburst on longwall face
Location	Austar Coal Mine

Overview

A pressure bump of significant intensity was immediately followed by a "dynamic" ejection of coal from the longwall B2 face during production at Austar Coal Mine at 5.15 am on 19 August 2016.

The ejection of coal from the face resulted in two workers being knocked to the ground and struck by small pieces of coal. They suffered no serious injuries.

Figure 1: Broken coal on the face side of spill trays following the reported coal burst.[i]

Figure 2: Ejected coal in the walkway as a result of the coal burst.[ii]

The mine

Austar Coal Mine (Austar) is a deep underground coal mine located near Paxton about 10 kilometres south west of Cessnock in the Hunter Valley, NSW.

Production in the Greta seam (4m thick) is achieved using the Longwall mining method and bolter-miners used for roadway development.

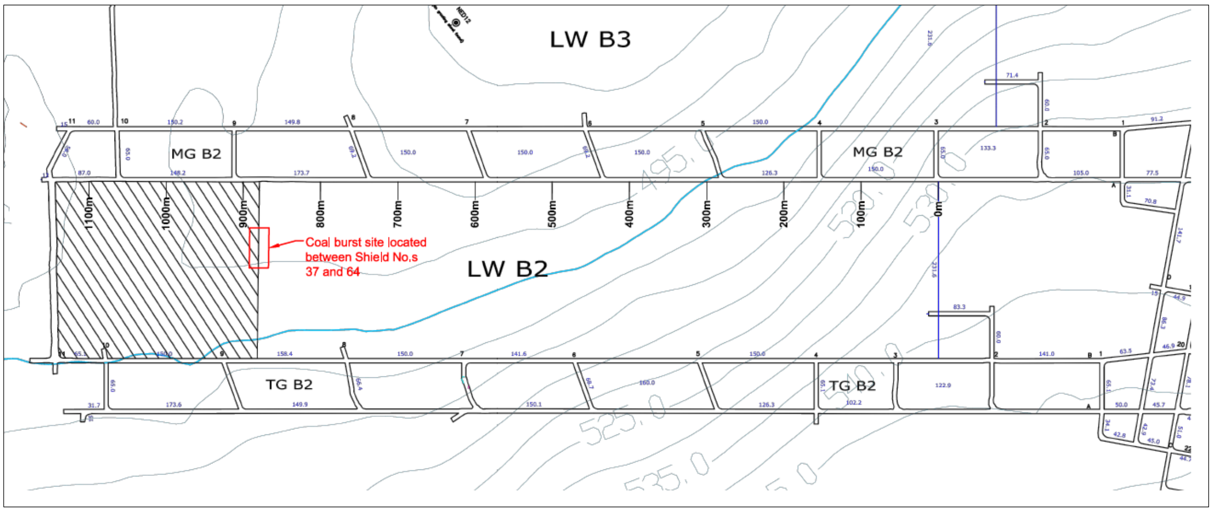
The mine produced 1.64 Mt of raw coal in 2013-14.[iii]

The incident site

The incident site was on longwall B2 with the face at the 872 m mark as shown in Figure. 3. The longwall had retreated 260 m from the starting position, having just passed the “square” goaf position. The depth of cover at the incident site was approximately 495 m.

The longwall panel width was 237 m with 131 hydraulic shield supports.

Figure 3: Location of the incident[iv]



The incident

At the time of the incident, the shearer was cutting towards the tailgate when a significant pressure bump and subsequent dynamic ejection of coal (coal burst) occurred from an area of the coal face between shields 37 to 64.

Two workers were positioned at shield 51, with a further three workers adjacent to the shearer at shield 90. The two workers at shield 51 were knocked to the ground by the force of the coal burst and were sprayed with coal dust and small pieces of coal. No workers suffered serious injury.

It is estimated that about 11 to 12 tonnes of coal (in total) was projected from the face over an area covering approximately 50 m of face length with some 400 kg travelling up to 7 m into the walkway area of the powered supports.

Actions post incident

A prohibition notice was issued by Mine Safety inspectors suspending longwall operations pending a geotechnical assessment and review of the incident and associated control measures.

Both Austar and the Inspectorate gained independent geotechnical advice. Both reports confirmed that the incident was defined as a low level coal burst event and not as a result of a goaf fall or an outburst of gas.

Under the direction of the regulator and in agreement with the mine operator, the following actions were taken.

Austar implemented a review of control measures associated with the *Coal burst management plan* which included, but was not limited to

1. Installation of coal burst conveyor mats between the coal face and the powered support walkway in addition to operating the roof support flipper bars at 90 degrees to the roof support canopy.
2. Reducing exposure of the workers on the coal face by limiting the number of workers during production and maintenance activities.
3. Providing direction as to the position of workers during production and maintenance activities.
4. Reviewing the cutting methods.
5. Ensuring all workers are trained in, and made aware of, the new operating procedures for longwall B2.

In addition, the regulator imposed that:

a) the *Coal burst management plan* and associated trigger action response plan (TARP) be adjusted to the high hazard level, which would remain in place for the remaining life of longwall B2, and

b) Austar must immediately notify the regulator of any coal burst or dynamic strata failure event during the extraction of longwall B2.

Contributing factors

Coal burst is best described as a sudden and dynamic failure of overstressed coal or rock resulting in the release of stored energy. It is associated with a seismic event often referred to as a pressure bump.

Contributing factors to a coal burst may include but are not limited to:

- depth of cover
- pillar/panel design and layout
- lithology, particularly when thick, strong and rigid strata is overlying the seam being mined
- geological features such as sandstone channels, seam rolls and faulting
- seam thickness.

The incidence of coal burst is not well-documented in Australia to date with only one previous recorded incident associated when there was a double fatality in a development panel in 2014. This incident occurred at Austar.[v]

Investigation and collection of data will continue for the most recent incident to increase the knowledge associated with coal bursts. The following factors have been identified as potential contributors to this incident:

1. **Depth of cover.** At the time of the incident the longwall was operating at a depth of 495 m.
2. **Overriding stiff massive strata.** The Greta seam being mined is 10 to 20 m below the base of the Branxton Formation. This formation is more than 400 m thick and comprises of sandstone and conglomerate units that are generally described as strong and massive.
3. **Geological structures.**
    a. Sandstone channels and seam rolls were identified in the panel on development and were present at the location of the coal burst.
    b. The longwall is between two faulted zones within a regional anticline.
4. **Mining layout and sequence.** Longwall B2 was the first longwall block in the area. With a face width of 230 m and having retreated some 260 m from the starting position, most of the weight of the undermined strata would be concentrated on the longwall face and the side panel abutments.
5. **Concentrated loading from overlying strata.** Fracturing of stiff beds in the super incumbent strata resulting in a sudden release of energy.

Observations

Research has identified that coal bursts were recorded in countries such as Poland, Czechoslovakia, USA and China. Despite this research, coal burst remains one of the unresolved technical problems facing the coal mining industry as stated at the recent International Workshop on Coal Burst Experience and Research Direction, at UNSW in August 2016.[vi] Further research is continuing through the Australian Coal Industry's Research Program (ACARP).

At this time, prediction of a coal burst event is not entirely possible. Mine operators therefore need to ensure that they are aware of the most significant contributing factors associated with a coal burst event such as:

1. the stress environment being sufficiently high to result in rock failure
2. a situation in which a state of unstable equilibrium could exist such as low friction bedding planes
3. a change in the loading system. For example, a reduction in rock strength due to a local change in rock material or structural properties, an increase in stress associated with geological structure or decrease in confinement due to formation of one or more excavations.
4. stored energy generated by increased depth of mining, bridging strata or geological structures.

Additionally, mine operators should be aware of current research into the identification of coal burst potential and mitigation techniques. Sources of information are available through industry forums, conferences, research bodies and reputable full text academic databases.

About this information release

The NSW Resource Regulator as the WHS regulator for mining has issued this information to draw attention to the occurrence of a serious incident in the mining industry. The investigation may be ongoing. Further information may be published as it becomes available.
The information contained in this publication is based on knowledge and understanding at the time of writing. However, because of advances in knowledge, users are reminded of the need to ensure that the information upon which they rely is up to date and to check the currency of the information with the appropriate officer of the Department of Industry, Resources Regulator, Mine Safety or the user's independent adviser.
For information about health and safety regulation on mine sites contact a mines inspector at one of our local offices: www.resourcesandenergy.nsw.gov.au/miners-and-explorers/safety-and-health/mine-safety-offices

PUB16/451

Issued by

Tony Forster
Chief Inspector of Mines
Appointed pursuant to Work Health and Safety (Mines and Petroleum Sites) Act 2013

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[i] Photo supplied by Austar Mine Pty Ltd
[ii] Photo supplied by Austar Mine Pty Ltd
[iii] NSW Coal Industry Report 2014
[iv] Plan supplied by Austar Mine Pty Ltd
[v] www.resourcesandenergy.nsw.gov.au/miners-and-explorers/safety-and-health/incidents/incident-updates
[vi] Professor Ismet Canbulat – Professor and Kenneth Finlay Chair of Rock Mechanics
Mining Engineering - UNSW School of Mining

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NSW RESOURCES REGULATOR MINE SAFETY

Independent technical expert's report

Appendix to Investigation Information Release IIR16-06 - Austar coal burst

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Amendment schedule		
Date	*Version #*	*Amendment*

Galvin & Associates Pty Ltd

Coal burst on longwall B2 face at Austar Coal Mine on 19 August 2016.

Summary of technical advice of 4 September 2016

For the NSW Department of Industry, Resources Regulator, Mine Safety

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Contents

1. Introduction

This report summarises the technical advice provided by the author on 4 September 2016 to the NSW Department of Industry in relation to an incident at Austar Coal Mine on 19 August 2016. The incident was associated with a dynamic event in which coal was blown out from the face of longwall B2 and over the AFC spill plates, impacting on two mine workers.

The advice is based on a site inspection by the author on 22 August 2016, responses to questions of mine management and employees at that time, and information contained in material provided by the mine operator to the regulator, pursuant to the *Work Health and Safety Act 2011.*

2. Definitions and prerequisites for a coal burst

There is a range of confusion and ambiguity associated with the definition of seismic events in coal mining. This report is based on the definitions adopted in the investigation of the fatal coal burst event at Austar Coal Mine in 2014 (Galvin & Hebblewhite, 2015) and refined in Galvin (2016) and Hebblewhite & Galvin (2016).

They are:

Bump: A pressure bump is a dynamic release of energy within the rock mass that is of sufficient magnitude to generate an audible signal, ground vibration and potential for displacement of loose or fractured material into the mine workings. It is usually associated with either failure of intact rock or failure and displacement along a geological structure. In the USA, a pressure bump is sometimes referred to as a **bounce**.

Coal burst: A pressure burst (or coal burst) is a pressure bump that actually results in dynamic rock failure (including coal) in the vicinity of a mining excavation, resulting in high velocity expulsion of the failed material into the excavation. The energy levels and associated velocities are sufficiently high to result in significant damage to, and even destruction of, conventional rock mass support and reinforcement systems.

In any situation, four conditions have to be satisfied simultaneously in order for a dynamic (violent) rock failure to occur. The first is self-evident and implicit in the other three conditions reported by Salamon & Wagner (1979). These four conditions are:

1. The stress environment must be sufficiently high to result in rock failure.
2. A situation must exist which can result in a state of unstable equilibrium. This could be a low friction bedding plane, for example, where the potential exists for the coefficient of friction to drop rapidly from its static to dynamic value once movement is initiated along this plane.
3. A change in the loading system. Potential triggers include, for example, a reduction in system strength due to a local change in rock mass material or structural properties, an increase in system stress associated with a local geological structure, or a decrease in confinement due to the formation of one or more excavations.
4. A large amount of energy has to be stored in the system. This energy can be generated, for example, by depth of mining, bridging strata or geological structures.

3. Classifying and understanding the incident

Interviews and analysis of coal monitoring data has established that the incident was not a coal outburst. Underground observations established that coal was ejected with some force and that the incident definitely constituted a 'blow out' of the face. Having subsequently been provided with more detailed information, I consider that the incident satisfies the definition and prerequisites of a coal burst.

An important consideration is whether the incident was a coal burst in its own right, or whether it was triggered in response to dynamic loading induced by a primary seismic event located elsewhere. In the absence of a microseismic network, this cannot be categorically determined. However, on the basis of the information available at this time (4 September 2016), it appears more likely to have been triggered by a seismic event associated with fracturing of the superincumbent strata and/or the unclamping and slippage of a nearby fault system.

If this is the case, it can have serious implications for managing the risk of coal bursts. In particular, in some circumstances, observations and behaviours about the working face may be poor indicators of an elevated risk of a coal burst.

Coal bursts are complex phenomena with more than one cause. They are associated with a number of contributory factors, with a critical change in any one factor possibly being sufficient to cause a change in the loading system sufficient to trigger an uncontrolled release of energy.

Coal bursts cannot be predicted. In order to better appreciate the nature of the incident of 19 August 2016 and how to best manage the risk of future coal bursts, this report briefly explores and assesses some of the potential contributory factors.

4. The mine layout

The incident occurred on the face of longwall B2, which is the first longwall panel in a series being developed in a 'virgin' area of the Greta Seam at Austar Coal Mine. At the time, the 220 m wide face had retreated a distance of about 260 m at a depth of approximately 495 m. This means that the panel had a width to depth ratio, W/H, of 0.44 and had retreated to slightly past the square position. The implications of this geometry are:

- The panel fell in the sub-critical range in respect of subsurface and surface fracturing, caving and vertical displacement (subsidence).
- The height of fracturing would be limited, with most of the weight of the undermined strata being transferred to the panel abutments.
- Because the panel was in 'virgin' ground, the corners of the panel would be subjected to the lowest abutment stress (since there is solid coal on three sides, or quadrants, to carry the abutment weight), while the middle half of each panel side (away from the influence of the corners) would be the most severely loaded.
- In subsequent panels, peak abutment stress will be at the tailgate end of these longwall faces and may be higher than in longwall B2, since the longwall face and chain pillar(s) at the tailgate end in subsequent panels are now surrounded by goaf (rather than solid) in three quadrants.
- Depending on the extent of fracturing of the immediate and upper roof strata, face abutment stress could continue to increase with further face retreat in longwall B2, potentially reaching a final value that is double that when the panel was square. Theoretically, this final state is reached when the face has retreated 2.5 times the panel width, with 90% of the final value being reached when face retreat equals twice panel width. In practice, fracturing and subsidence of the superincumbent strata is likely to result in the plateau stress value being both lower and reached at an earlier stage of extraction. Notwithstanding this:
  - The state of stress on the face of longwall B2 could increase with further mining and is likely to be higher around the tailgate end (including chain pillars) in subsequent longwall panels in this series.

The south-west corner of longwall B2 (MG B2 and installation face) has a stand-off distance of 50 m from the predicted location of the Barraba Fault. This fault has computed throws in the range of 3 to 18 m in this area and apparently dips back over the top of longwall B2. Longwall panels have already been extracted on the other side of this faulted zone. The potential implications of this mine layout include:

- The faulted zone may have already been laterally 'unclamped' to some extent by previous mining.

- Extraction of longwall B2 may result in additional lateral unclamping of the faulted zone.
- At the same time, both past mining and existing mining is likely to result in a significant increase in the 'vertical' component of stress in the faulted zone.
- If the fault hades (dips) over the goaf of Longwall B2, it may change the caving behaviour of the superincumbent strata.
- The mining-induced unclamping of a fault is an established source of seismicity resulting from reactivation of movement on the fault plane.

The geological plan and authorities to mine (ATMs) note a number of other geological features in the vicinity of the incident site. These include a fault with a 0.7m throw between 8 and 9 cut-through in MG B1 (tailgate) of longwall B2[1]; the presence of a sandstone channel (lense) in the first 15 m of the immediate roof[2] (which appears to have been described as *'zone of frequent channel in immediate roof'* in the ATMs[3]); *'strike slip faulting'*; *'horizontal stress orientation relative to strike slip able to form drag features'*; and *'horizontal stress in relation to direction of driveage allows stress concentration in direction of shear stress propagation'*.[4]

The implication of this type of geological setting at depth, in association with changing the stress environment and loading system by mining, is that the conditions are conducive to initiating seismic events.

5. Preceding events

The deputies' statutory reports preceding the incident record the following points of note:

11/8/16	Night shift	*3/10 pressure bump while cutting into T/G..*
11/8/16	Afternoon shift	*Stone intrusion 60/61..stone intrusion 9-16*
13/8/16	Day shift	*Ribs blown out 2mtr on block side*[5]
15/8/16	Day shift	*Minor stone intrusion across face*
16/8/16	Night shift	*Moderate coal burst on face*

It should be confirmed if the event of 16/8/16 was indeed a coal burst, or whether the terminology has been used loosely to describe a coal bump.

6. The incident site and circumstances

At the time of my site visit on 22 August 2016, some three days after the incident, the face and adjacent gate roads were very quiet. The longwall powered supports were not in yield or displaying signs of being subjected to a periodic weighting cycle, the face was not spalling and there was no noise emanating from the goaf or from the roof and floor strata. The face and gate road ribs did not display signs of excessive abutment stress.

Figure 1 to Figure 3 show aspects of the longwall face. Coal was blown from the longwall face over a length of some 50 m and to a depth of about 1 to 1.5 m. According to analysis undertaken by the mine owner at the request of investigators after visiting the site on 22 August 2016, approximately 11 to 12 tonnes of broken coal was ejected from the face between powered supports #37 to 64 and, of this, around 0.4 tonnes had landed on the walkway side of the spill trays. Coal had been ejected some 6 to 7 m back from the face.

[1] ATM MG B1 8CT to install road
[2] ATM001 19082016 longwall B2 CH 872 – Ch 736m
[3] ATM001 19082016 longwall B2 CH 872 – Ch 736m; LWB2_ATM_2016.07.06.dwg
[4] 19022016 ATM MG B2 8ct to 9ct.
[5] Note: The term 'blown out' appears to be used by some at the mine to describe rib spall and slumping, as opposed to the ejection of coal from the ribs.

Figure 1: Face condition towards maingate end showing minimal signs of high abutment stress and spalling and negligible debris on the walkway side of the AFC.

Figure 2: Face condition in burst area, showing the depth of rib blow out (note that the coal had already been run off the AFC).

Figure 3: Ejected coal around and between the pontoons of #50 support.

It was reported that the incident coincided with a bump that registered between 7 and 9 (out of 10) on the Austar pressure bump scale. It also coincided with a surface vibration event of 25.2 mm/s, described as one of the largest events recorded since this monitoring system was installed. A total of eight days had elapsed since the last significant event of 10 mm/s.[6]

Surface subsidence behaviour is an indicator of the caving behaviour of the superincumbent strata and, therefore, how abutment stress is distributed and when stress relief occurs. A limited amount of relevant surface subsidence data was available at the time of writing. Further and more detailed analysis of surface subsidence data is warranted in understanding the mechanics of caving and the role that this is likely to be playing in producing seismic events.

The surface subsidence information provided shows that at least four adjacent longwall panels need to be extracted before maximum surface subsidence is reached and that the bulk of the superincumbent strata bridges across the first panel in a series of longwall panels at Austar Coal Mine. It also appears to indicate an increased rate of surface subsidence in the four days immediately preceding the incident. This is not surprising, with the measured surface response being consistent with fracturing of the superincumbent strata only extending to a limited height above the seam level.

The implications of these observations and analysis are:

- The longwall face did not appear to have been under the influence of high abutment stress immediately before or after the incident.
- This suggests that the face was being shielded to a degree from high abutment stress by the bridging superincumbent strata, in which case the energy source to drive the dynamic failure of the coal face most likely came from a remote source.

[6] Golders report of 25/8/16.

- Two of the most likely sources of this energy release were the fracturing of stiff bed(s) in the superincumbent strata and reactivation of geological faulting in the region.
- The protection of the face from high abutment stress may enhance the reliability of some indicators of vulnerability to coal bursts, such as presence of vertical ribsides. However, it can decrease the reliability of others, such as the volume of cuttings produced from test holes.
- Based on surface subsidence observations and geological characteristics, dynamic failure of stiff beds in the superincumbent strata is likely to occur during extraction of longwall B3 and both the chain pillars and longwall face at the tailgate end of this next longwall panel should experience higher abutment stresses than longwall B2.

7. Assessment in the context of past incidents

Following the fatal coal burst that occurred in B heading of Maingate A9 development roadway at Austar Coal Mine on 15 April 2014, Professor Bruce Hebblewhite and I were engaged by the Mine Safety Investigation Unit to assist with the investigation. Among other things, we concluded that it not possible on the evidence available to categorically state the precise causes of the pressure burst or the relative magnitude of the contributory factors with a high degree of certainty. The failure mechanism was complex and a combination of multiple factors was involved (Hebblewhite & Galvin, 2016).

This combination of factors included high stress associated with depth of mining, supplemented by additional stress concentrations resulting from any or all of: regional faulting zones immediately adjacent to the event location; lensing and variations in stiff overburden sandstone units; the presence of quite intense regional geological structure in the area, combined with severely distorted and complex local geology; the presence of massive sandstone units within the immediate +20 m of overburden roof, and the possibility of massive units also in the floor; and a very dominant, smooth horizontal shear plane represented by the Dosco Band, providing a dynamic shear failure surface below which the crushed and sheared coal could move. The development mining provided a trigger to destabilise the rock material above the burst zone in proximity to the fault surfaces ahead of mining as well as resulting in a loss of confinement to the coal ribline that was undoubtedly subject to high levels of vertical stress.

During that investigation and subsequently, I received a number of anecdotal reports of past coal burst events in first workings in mines extracting the Greta Seam. At the time of writing, there was a lack of information to confirm if any of these events did constitute a coal burst.

Similarly, anecdotal reports have emerged of incidents on past longwall faces at the mine, before its name was changed to Austar Coal Mine. One of these was associated with a dynamic event that is reported to have resulted in an eruption of coal that filled the AFC as it was being pushed over, causing damage to six push cylinders. The incident was reported to have occurred sometime during the extraction of longwall 3 to longwall 5 at Ellalong Colliery. These and the preceding two longwall faces were only 150 m wide, meaning that the superincumbent strata would not have fully subsided at the time of the incident.[7]

The nature of the 14 April 2014 incident is significant because if the circumstances that were associated with it were to be encountered on a longwall face, the potential for an outburst would be at least as great and, in all probability, greater. Some (but not all) of factors that Galvin & Hebblewhite (2015) associated with the fatal coal burst in 2014 are also associated with longwall B2. However, the stress concentrations on the face of longwall B2 could be expected at times to be significantly higher than in B Heading of Maingate A9.

The implications of this historical information include:

[7] [Updated aside: This may or may not be the same event that Galvin & Hebblewhite (2015) reported, in their investigation report into the double fatality coal burst of 15 April 2014, previously dislodged the shearer from its tracks in longwall 4.]

- Risk assessment should give consideration to the potential for a larger coal burst on the longwall face than that associated with the incident on 19 August 2016.
- Risk assessment should give consideration to whether the potential for a coal burst on the longwall face is at least as high, or higher, in the vicinity of active coal extraction; that is, in the vicinity of the shearer. This is an important consideration when developing controls and assessing the residual risk with these controls in place.
- Determination of the location and cause of seismicity can give direction as to where a coal burst is more likely to occur.
- Determination of the location and cause of seismicity gives direction to the nature and effectiveness of controls and the level of residual risk.
- Determination of the location and cause of seismicity requires the use of microseismic monitoring.

8. Longwall B2 coal burst management plan

A longwall B2 Coal Burst Management Plan with an approved review date of 07 July 2016 was in place at the time of the incident. The plan begins by noting that *'Austar Coal Mine has not had a history of coal bursts in or around the longwall extraction district'*. While this may be correct for the period that the mine has been owned by Yancoal, anecdotal reports now suggest that coal bursts may have occurred in both development and longwall districts when the mine was previously operated as Southlands Colliery and, prior to that, as Ellalong Colliery.

It was reported that the risks and controls for coal burst during longwall mining were covered in a past risk assessment for longwall A8 extraction, and that the Coal Burst Management Plan was reviewed and updated based on an external coal burst assessment in 2016 for longwall B2. The management plan was referred to as a procedure *to be used as a guideline and a standard for the prediction, prevention and control, to mitigate the impacts of coal burst*.

It needs to be appreciated that no system has yet been developed that is capable of 'predicting' per se, the occurrence of a coal burst. Rather, systems (such as microseismic monitoring) can only identify an elevated potential for a coal burst, a point which appears to be acknowledged in Section 3 of the Coal Burst Management Plan.

The plan notes a number of controls within zones where an elevated potential for coal burst exists. One of these states that consideration should be given to using a modified uni-directional cutting sequence in high level coal burst hazard areas.

The management plan refers to advice from an external consulting company on the likelihood of a coal burst occurring on the longwall face. In this regard, it is stated that:

> *Similarly, it is assessed that the likelihood of a coal burst occurring on the longwall face is also considered to be low: this being primarily due to the absence of (i) any significant geological structures, (ii) high level periodic weighting and (iii) high abutment loads around the tailgate of the face.*

As longwall B2 was the first longwall in a 'virgin' area of the mine and had a sub-critical panel width-to-depth ratio, W/H, the abutment loads could be expected to be greater in the middle third to half of the face, with abutment load being least and of a similar value at the tailgate and maingate ends of the face. Only in subsequent longwall panels in the series would the highest abutment loads occur at the tailgate end.

No significant geological structures were observed during the author's underground inspection on 22 August 2016 and both visual observations and monitoring records of pressures in the legs of the powered supports indicated that the face was not experiencing high level periodic weighting at the time of the incident. Hence, the circumstances associated with the incident of 19 August 2016 did not fully align with the criteria used to assess the potential for a coal burst on a longwall face. Therefore, further consideration of the primary drivers of a coal burst at the mine is advisable. Two of these drivers may be the dynamic failure of massive superincumbent strata and the reactivation of movement on geological faults. Both of these drivers fall into the second category of coal burst described by Iannacchione & Zelanko (1995) and noted in Austar's Coal Burst Management Plan, namely 'seismic shock loading'. Microseismic monitoring is required for the study of this type of coal burst mechanism.

The Coal Burst Management Plan was based on three coal burst classifications, namely *Low Level Hazard*, *Moderate Level Hazard*, and *High Level Hazard.*[8] These classifications are premised on the potential for a coal burst to occur at a particular location relative to the remainder of the mining area. They are not based on consequence and are not associated with levels of risk, other than it is noted that a high hazard level requires further *detailed assessment (and potentially controls)*.

The Coal Burst Management Plan states that:

> *Although ranked as a major contributing factor in other parts of the world, in the case of Austar, there is no history of bursts prior to mining past square on the longwall face. Conservatively, Austar will consider the mid face area of the longwall face as a moderate level hazard for coal burst in the 2 identified areas of weighting potentially associated with the lower and upper strata square ups.*

This appears to recognise that in the specific case of longwall B2, the middle third to half of the face would be subjected to the highest abutment stress (peaking at mid-face). In my opinion, it was judicious of Austar Coal Mine to increase the hazard rating in the area defined by chainage 872 m to 770 m. The fact that the area was not experiencing periodic weighting at the time of the incident may simply reflect that up to that moment, the superincumbent strata was behaving as a plate and bridging over considerable spans with minimal deflection. In that case, the dynamic (brittle) failure of a lower portion of this plate could result in the sudden release of a considerable amount of stored energy.

The Coal Burst Management Plan defines a number of 'No Go' and 'Restricted Access Areas', with constraints being based on the assigned coal burst hazard level. In the case of a moderate level hazard zone, a deputy is required to wait 15 minutes to inspect the maingate after the shearer has progressed out of the maingate end, and 30 minutes in similar circumstances at the tailgate end. The entry constraints to the tailgate are also higher than at the maingate end when in a high level hazard zone. These requirements may need to reviewed/edited for the sake of consistency.

In a moderate level hazard zone, the plan provides for restricted access around the shearer 'as per standard operating procedure'. This is logical, as the extraction/cutting/mining process is a source of change in the loading system (pre-requisite No. 3) and a common trigger for pressure bursts in both hard and soft rock mines. It is noted for later reference that proposals to restart mining in longwall B2 rely on personnel remaining in close proximity to the shearer as a control.

Risk review longwall B2 coal burst

On 22 August 2016, Austar Coal Mine undertook a review of the risk of a coal burst occurring on longwall B2. The following comments are offered on the report pertaining to that review:

- The composition of the risk review team appears to have comprised only one external member, this being a consultant in geotechnical engineering. Specialist knowledge and understanding of the mechanics of coal pressure bursts within the review team would appear to have been limited to that of this consultant, albeit that many team members may have had extensive experience of coal pressure bumps.
- The review and associated controls are premised on the hazard level rating of the longwall face from chainage 872 m to 770 m remaining unchanged as a 'Moderate Coal Burst Hazard Level'.
- A high reliance is placed on restricting the number of personnel on the coal face and having them stay in close proximity to the shearer. The review report does not explain the reasoning behind some of the proposed controls. Aspects that would benefit from clarification include:

[8] Page 7 of the Coal Burst Management Plan

- Since the coal burst of 19 August 2016 occurred outside of the immediate vicinity of the shearer, was the review and development of controls based on an assumption that future coal bursts would also be confined to areas outside the immediate vicinity of the shearer? If so, experience (apparently including past experience at this mine when it was operated as Ellalong Colliery) would suggest that this is not always the case and that, in fact, the area in the vicinity of the shearer may be the more likely site of a coal burst (analogous to the 2014 incident in B8 gate road at the mine).
- What is the rational from a consequence perspective in restricting the number of persons on the face?

In relation to the second point (bullet), the question may be asked as to why if it is considered safe for up to four personnel to be on the face at the same time, it is not considered safe for six personnel to be on the face at the same time?

Alternatively, if the safety of all personnel cannot be assured, what criteria have been applied in determining that up to four persons can be exposed to the risk of injury? If the criteria was based on the space available around the shearer for these people to undertake all necessary operational functions while staying within the protection of the physical barrier provided by the shearer, then the review should be supported by a risk assessment of the likely effectiveness of the shearer as a control in the event of a coal burst.

It would also be insightful to conduct a comparative risk assessment between the protection provided by the shearer and that provided by the powered supports following the proposed changes to the way that they will be configured and operated in the future (e.g. flipper in a vertical position) and after the installation of any additional barriers (e.g. hungry boards on the AFC spill plates, conveyor belt curtains hung off the canopies of the powered supports).

Although the risk analysis to support the Coal Burst Management Plan provides a hazard ranking on the basis of likelihood, it gives minimal consideration to the consequences associated with a coal burst. These consequences are independent of likelihood, meaning, a severe injury or worse could just as easily result from a coal burst in low level hazard zone as it could in high level hazard zone. Hence, an argument may be made that controls to manage the consequences of a coal burst need to just as stringent and robust when operating in a low likelihood zone as when operating in a high likelihood zone. This is the logic behind also ranking risk assessment outcomes in terms as consequence (as per the advice of guidelines such as MDG-1010, 1997, 2011).

Given that a coal burst has now occurred in a zone that was thought at the time to have been classified conservatively as presenting a moderate level hazard, the question arises as to whether some of the controls previously identified for high level hazard zones should be applied to zones thought to present a moderate level hazard. In particular, should the cutting sequence revert to uni-di in these zones?

9. Concluding comments

- The incident on 19 August 2016, in which coal was ejected from the face of longwall B2 in front of powered supports #37 to 64, constituted a small coal burst.
- Given the lack of knowledge concerning the mechanics of pressure bumps and pressure bursts at Austar Coal Mine and past experiences of seismic events, both specific to the mining of the Greta Seam and to underground coal mining in general, further coal bursts of unspecified but possibly greater magnitude during the extraction of longwall B2 cannot be ruled out.
- The coal burst hazard rating system in place at Austar Coal Mine at the time of writing was based on the likelihood of a coal burst occurring and, importantly, not on the potential consequences of a coal burst.
- Microseismic monitoring is essential for developing an understanding of the mechanics of pressure bumps and pressure bursts at the mine which, in turn, gives insight into risk management controls.

- Pressure bursts cannot be predicted. Tools such as microseismic monitoring are aids for forecasting and for identifying areas with an increased potential to burst.
- Given the existing knowledge base, the most effective control is to remove workers from the longwall face. Since this is not achievable at present, the next most effective control is likely to be the presence of physical barriers between the coal face and operators. There may be a range of other controls.
- Controls need to be risk assessed in their own right in order to evaluate their likely effectiveness and to verify that they do not introduce new risks that may be unacceptable.
- Careful consideration will need to be given to the implications of the changed state of stress that will be associated with extracting subsequent longwall panels in this part of the mine.
- This may require a research effort that, in addition to using microseismic monitoring, should include the establishment of a data base of past incidents associated with mining the Greta Seam, analysis of past sub-surface and surface subsidence data and numerical modelling, in order to gain a better understanding of failure mechanics and hence, appropriate controls.
- These controls could include changes in the dimensions of panels and pillars and in face operating procedures.

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