Trade & Investment Mine Safety

Investigation Report

Fire and explosion on Longwall No 1 Tailgate at the Blakefield South Mine 5 January 2011

Published report prepared by the Investigation Unit, Thornton

May, 2012 www.resources.nsw.gov.au/safety

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Fire and Explosion on Longwall No. 1 Tailgate at the Blakefield South Mine
5 January 2011

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Published by NSW Trade & Investment

Report Date 8 May 2012

TRIM reference: 11/236

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Introduction

The incident that prompted this report

This investigation report sets out the events leading up to, and examines the possible causes of, an explosion underground at the Blakefield South Mine at 7.36pm on Wednesday 5 January 2011. Blakefield South Mine is operated by Bulga Underground Operations Pty Limited, known as Beltana Highwall Mining Pty Limited at the time of the incident.

There were 47 people working in the mine at the time of the explosion; all were evacuated safely from the mine. An underground fire was associated with the explosion and Blakefield South Mine was subsequently sealed. Blakefield South Mine was not able to be re-entered until 6 June 2011.

Overview

Location of the mine

The Bulga Coal Complex is approximately 15 km southwest of Singleton, 1 km north of Broke and 1.5 km east of Bulga, in the Upper Hunter Valley of New South Wales. Bulga Underground Operations Pty Limited comprises the underground coal mines that form part of the Bulga Coal Complex.

Mining history

Coal mining at what is now known as the Bulga Complex was started by the Broken Hill Proprietary (BHP) in 1982. It was then known as the Saxonvale Mine and was an open cut operation. In 1988 BHP transferred ownership of the mine to Elders Resources and the following year it was acquired by Oakbridge Pty Limited.

Oakbridge began underground coal mining in 1994 at the South Bulga Mine using the longwall method of mining. Coal was extracted from the Lower Whybrow seam. Longwall production at South Bulga Colliery ceased in 2002 after the extraction of approximately 30 million tonnes of coal from 13 longwall panels.[1]

Beltana Highwall Mining commenced longwall operations in 2003. Blakefield South Mine began longwall operations in June 2010 in the Blakefield seam. Production operations at the Beltana Highwall Mine ceased as of August 2011.

[1] Xstrata Coal, Bulga Complex Mining, 30 November 2011, <http://www.bulgacoal.com.au/EN/Pages/default.aspx>.

The operation

The mine:	Bulga Underground Operations Pty Limited (previously known as Beltana Highwall Mining Pty Limited at the time of the incident) – Blakefield South Mine
Mine location:	Broke NSW 2330
Colliery holder:	Bulga Coal Management Pty Limited
Colliery holding:	Comprised of ML 1494 *Mining Act 1992*, ML 1547 *Mining Act 1992*, CL 224 *Coal Mining Act 1973,* CL 219 *Coal Mining Act 1973.*
Operator of coal operation:	Bulga Underground Operations Pty Limited formerly Beltana Highwall Mining Pty Limited
Number of employees at coal operation:	309 (includes Beltana and Blakefield South mines)
Production 2010:	5,741,355 ROM tonnes

The companies

At the time of the explosion Beltana Underground Operations Pty Limited was known as Beltana Highwall Mining Pty Limited. Beltana Highwall Mining comprised two underground longwall operations, the Beltana Highwall Mine and Blakefield South Mine. Beltana Highwall Mining operated in the Lower Wybrow seam.

Bulga Underground Operations is managed by Bulga Coal Management Pty Limited which in turn is managed by Xstrata Coal.

Bulga Underground Operations is one of the Xstrata Coal group's coal mining operations. Xstrata Coal is the world's largest producer of export thermal coal and a significant producer of premium quality hard coking coal and semi-soft coal. With headquarters in Sydney, Xstrata Coal has interests in over 30 operating coal mines in Australia, South Africa and Colombia and an exploration project in Nova Scotia, Canada[2]

The colliery holder was identified as Bulga Coal Management Pty Limited, a joint venture of Saxonvale Coal Pty Limited and Nippon Steel Australia Pty Ltd. The ultimate holding company, of Bulga Coal Management Pty Limited is AZSA Holdings Pty Limited.

[2] http://www.xstratacoal.com/EN/AboutUs/Pages/default.aspx

The mine operator

Bulga Underground Operations is the nominated mine operator under section 17 of the *Coal Mine Health and Safety Act 2002* and operates the mine on behalf of the Bulga Joint Venture (BJV).

Bulga Underground Operations is 68.25% owned by Xstrata Coal through its various management and ownership companies. It is managed by Xstrata Coal NSW on behalf of the Bulga Joint Venture.[3]

Bulga Underground Operations is a wholly owned subsidiary of Bulga Coal Management Pty Limited.

The ultimate holding company of Beltana Highwall Mining Pty Limited was Oakbridge Pty Limited.

The mining operation

Blakefield South Mine has been developed over the last five years with Longwall No 1 (LW1) starting production in June 2010. The longwall is 325 metres wide and is representative of a trend for ever wider longwalls. It was intended that after the completion of LW1, the next wall would be 405 m wide. Large quantities of air are passed through the longwall to remove dust and gas. Bulga Underground Operations had installed two ventilation shafts in Blakefield South Mine, each with three fans. The mine operated a forcing/exhaust ventilation system (more commonly referred to as a push/pull ventilation system) with Ventilation Shaft No 1 pushing air into the mine and Ventilation Shaft No 2 pulling air out of the mine. Normally air is pulled through the mine only.

The push/pull system of ventilation is designed to reduce the pressure difference between the mine air along the longwall face and the surface so that, theoretically, the absolute pressure along the face is the same as the surface absolute pressure. This reduces the likelihood of the goaf atmosphere that is high in methane (CH4), and therefore inert (note that the atmosphere in the goaf of LW1 contained 80 to 90% CH4 at the time of the incident),[4] mixing with oxygen drawn from the surface or being drawn from the goaf out into the mine workings.

Reducing the available oxygen diminishes the risk of two unwanted scenarios from occurring: the development of an explosive atmosphere in the goaf and spontaneous combustion.

Note: The ventilation of the mine is discussed in greater detail in the section titled Blakefield South Mine Ventilation.

Blakefield South Mine is also the world's first longwall mining operation to use an 11 kV powered armoured face conveyor (AFC) in a hazardous zone, defined by section 3 of the *Coal Mine Health and Safety Regulation 2006*. The greater width of the longwall combined with increased power to the shearer requiring greater power to drive the AFC.

LW1 utilises 158 x 2.0 m wide 1270 tonne yield load powered roof supports. The AFC was the most powerful in the world (when operating) with: a 400 kW crusher, a 600 kW x

[3] http://www.xstratacoal.com/EN/Operations/Pages/CoalOperations.aspx

[4] Readings of the goaf atmosphere taken by gas monitoring from the gas drainage wells.

1550mm wide beam stage loader (BSL) and two 1600 kW x 1100 mm AFC drives (upgradable to 3 x 1 600 kw). The shearer has 1000 kW rated ranging arms, 860 kW cutter motors and 150 kW mega drive haulage.[5]

Figures 1 and 2 below show longwall roof supports and a longwall shearer similar to the roof supports and shearer that were in use on the face of LW1.

Figure 1: Typical longwall face showing chocks and AFC
http://www.joy.com/en/Joy/Products/Longwall-Systems.htm Complete Longwall Systems Brochure

Figure 2: Longwall face Beltana Highwall mine showing shearer and longwall chocks
Photo by M. Freeman, 24 April 2010

[5] http://www.excellenceawards.org.au/2010_finalists/2010-finalist-37.html

Investigation

It was determined on 13 January 2011 that the incident would be investigated by the Investigation Unit. On 14 January 2011 the Investigation Unit Manager, Steven Millington and Investigator Tim Flowers attended the mine.

The mine was sealed at this time and no inspection of the scene would be possible until the mine had been safely recovered. The investigation concentrated on interviewing all relevant witnesses and appropriate people in management, and collecting documents to begin the process of identifying the cause(s) of the explosion.

On 6 June 2011 the mine, excluding LW1, was successfully reventilated after one earlier failed attempt (on 15 February 2011). The longwall was remotely sealed from the surface via boreholes drilled from the surface to intersect LW1 gate roads at predetermined points. A combination of fly ash and Rocsil (a brand of rapid expanding fire resistant anti-static foam)[6] was pumped down these holes to seal LW1 from the rest of the mine. Once the atmosphere in the mine was rendered safe it was possible to inspect the mine, and in particular, the electrical apparatus leading into the mine.

Once the development headings had been reventilated work began on the reventilation of the longwall gate roads. This was undertaken via a number of stages whereby the mine's rescue teams would enter through the seals, then advance a number of cut-throughs before erecting a further seal so that the outbye seal could be fully breached. This process concluded in December 2011.

To date the longwall has not been recovered.

One of the mine's rescue teams was able to access the longwall face as far as the tailgate and reported surprisingly little damage down the length of the face. The team collected some articles from the tailgate area and a dust sample; otherwise the face area and the tailgate have not been thoroughly inspected or examined.

The incident

At 7.36pm on Wednesday 5 January 2011 an explosion occurred in the vicinity of LW1 tailgate at the Blakefield South Mine.

The underground crew working at the LW1 panel that evening consisted of a longwall crew supervisor/deputy, shearer operator, production fitter/maintenance supervisor, technician/electrician, bootend attendant, mechanical technician, longwall operator, electrician/technician, electrician and an electrician/technician.

At the time of the explosion LW1 was stopped for maintenance. Three of the 10 crew members were having a meal break at the crib room at 17 cut-through. Five of the crew were repairing flight bars on the AFC at the maingate. A production fitter/maintenance supervisor was two thirds of the way along the wall at No 130 support marking loose bolts.

[6] Wilson Mining Services, Rocsil Foam Rapid Cavity Filler, (9 March 2011) <http://www.wilsonmining.com.au/Rocsil.htm>.

The force of the blast knocked the production fitter/maintenance supervisor off his feet. The overpressure created by the blast was still of sufficient strength when it passed the maingate, some 325 m away, to require the workmen to brace themselves. The pulse from the explosion could be felt all the way to the Mains crib room and at the entry to Maingate 2 and Maingate 3 some two to three kilometres away.

The following is a description of events that occurred at the time of the explosion by the crew supervisor/deputy and the production fitter/maintenance supervisor:

The production fitter/maintenance supervisor felt his ears pop at about 7.30pm.

"I felt … a change in pressure and then I felt like a shockwave hit me and then a really loud crack … it sounded like it was right next to my ears," he told investigators. "And, then the shockwave did knock me over, probably a bit over a metre, knocked me back towards the maingate. "

Blinded by the dust, he was only aware of an unusual odour.

"Something which was really different was the smell. It smelt like gunpowder, kind of like cordite after you shoot. It's a real distinctive smell and I'll never forget that smell."

Unsure of what had happened, the man ran for the maingate while the deputy called out to see if he was injured.

"I've never experienced (an outburst) before but that was just the first thing that came to my mind," he said.

The deputy told investigators that at 7.25pm he sent two of the men who were cleaning to the crib. He reported that the three men on the armoured face conveyor had isolated power.

"So we still had power on the face in the form of hydraulics and face lights. All other power was isolated at the maingate," he told investigators.

Two men were on the face digging out and starting to replace a dog bone while the production fitter/maintenance supervisor had the job of walking along the armoured face conveyor chain with a tin of spray paint, identifying loose nuts and missing bolts.

The deputy and an electrician remained at the maingate.

"Then there was a massive windblast. Huge. It blew totally against natural ventilation of the mine. Air comes in the maingate, across the face, out the tailgate. It blew outbye, across the face and back up the belt. Never quite blew us over, but if you didn't brace yourself it would have," the deputy said. "It was rather large. Very unexpected. Within seconds of the blow was the big suck back. The suck back was stronger than the blow."

Unable to see through the dust, the deputy's first thoughts were for the safety of the production fitter/maintenance supervisor. Using the communication system he asked what was happening.

"What, you right? What's going on? Within seconds, he answered me. His voice was frantic."

The deputy headed straight for the tailgate with the rest of the men following him.

"I've met (him) along the face, probably a third of the way along the face. I was walking, he was running."

"He told me he got bowled over, there was a loud bang and a distinct smell … and he said 'Something's happened up there man, something's happened'. He was okay physically, but his mind wasn't okay. He had a bit of grazing off the forearm and he was rubbing his shin … but other than that he was physically okay. He wasn't injured, but very shaken."

The other three men stayed with the production fitter/maintenance supervisor while the deputy continued to the tailgate. A shearer operator, who had been in the crib and walked up after the blast, accompanied him. The deputy noted that the face conditions looked good. The face lights and hydraulics were still on. Walking up the face, roof conditions looked fine, and the men saw nothing out of place. But as they approached the tailgate there was a distinct smell.

"I can't describe the smell. I must say I haven't quite smelt this smell before," he told investigators. "(The production fitter/maintenance supervisor) commented it smelt like burnt gunpowder, but I've never smelt that so I don't know. But it was a different smell, it was more a chemical smell. And it was strong."

The pair continued towards the tailgate, where the deputy heard a bit of rumbling.

"It wasn't a goaf rumble, it was like a thunder rumble, but it sounded a long way away. Then I said, 'Oh you hear that? That sounds like it's back in the goaf a fair way'.

"It wasn't close. It was a deep rumble. That went on for a couple of seconds and then stopped."

There was more rumbling.

"It sort of would go for a few seconds and then it'd stop for a while, then she'd happen again. It was just enough to get my ears pricked and say, 'You hear that mate? That's unusual, there's something strange'."

The tailgate drive on the longwall face is large and the deputy was expecting to see something unusual by now. A gas monitor alarm went off, reading 62 parts per million carbon monoxide (CO).

"Ah, there's something unusual here", he said. "You know, usually we don't have CO, especially at these levels."

And then he noticed something new.

"Usually, we've got 45, 50 cubic metres of air, going across the face. At the tailgate drive it usually whistles through there. Ventilation after the blow and the suck returned back to normal. But in this tailgate drive area it felt, very still and calm and, not warm. It's always sort of warmish up in that area because of the motor and (equipment)"

The pair walked to the tailgate drive and the deputy looked ahead to make sure it was safe to continue.

"When I stuck my head out … I had the shock of my life. I went from a reasonably calm state of mind to an absolute panic. When I stuck my head out there were flames. "

Flames up to eight metres long were coming back from the goaf edge and from the roadway fanning out of the goaf and around the cut-through. The deputy turned and yelled to get out. In fear of his life, he was running and waiting for a bang to happen.

"Usually when you walk across the face you've got to zigzag … and it's hard to walk. I don't know what I was stepping on but I was leapfrogging something and I was just going straight."

Figure 3 and 4 below are diagrams drawn by the deputy.

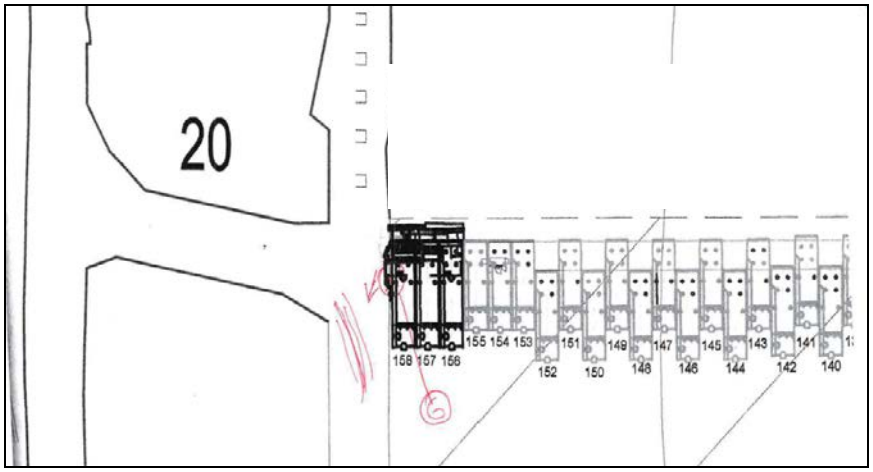

Figure 3: Extract from interview with deputy: Diagram showing the location of the flames in the tailgate area fanning around into 20 cut-through (*Chain number removed for clarity)*

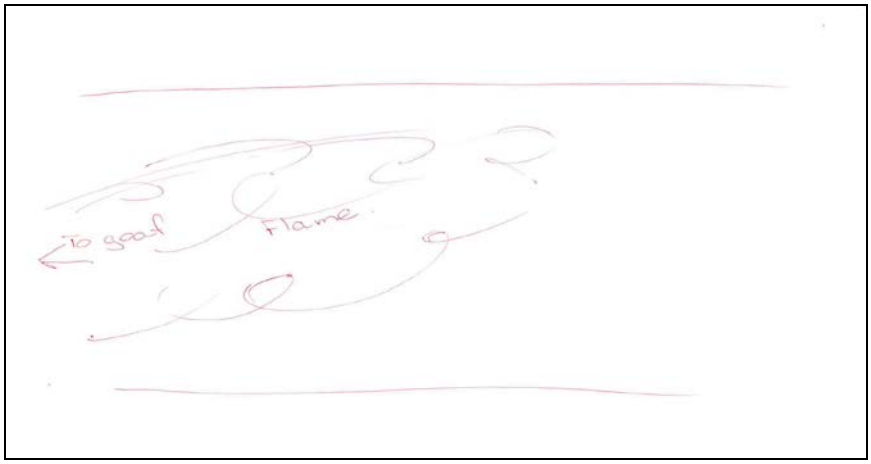

Figure 4: Extract from interview with deputy: Diagram showing long fanning flames emanating from the goaf area.

Circumstances of the incident

At the time of the explosion there was a thunderstorm taking place over the mine and data collected from the Bureau of Meteorology and other lightning detection sources suggest that a number of lightning strikes occurred near the mine surface at the time of the incident.

Blakefield South Mine is the first mine in NSW to have 11 kV power supply all the way to the tailgate drive motor. The issue of the use of the 11 kV power supply in this context is not without some controversy and a lengthy approval process was necessary between Bulga Underground Operations and the department.

At the time of the incident, however, (according to information gathered during interviews and the observed isolations on the isolation points on Maingate 1) the power to the tailgate drive motor was isolated to allow for maintenance work to be undertaken. This does not preclude electrical energy as a source of ignition but does diminish the likelihood that the 11 kV supply to the tailgate was the source of the ignition.

The mine was not producing coal at the time of the incident and there had been little to no production from any of the underground production areas since the end of the nightshift at 7 am that morning. The last full production from LW1 was on the preceding nightshift. In the preceding days the longwall had been producing at very high production rates with LW1 producing approximately 22,000 tonnes and advancing some 21 metres on the day before the incident.[7]

It should be noted that as LW1 retreated, a number of tasks had to be performed to facilitate that advance. It was crucial to alter the ventilation to accommodate that advance. It was necessary that as the wall passed each cut-through in the tailgate roadway, a full explosion rated seal be completed in the previous cut-through on the inbye side, and that at the next outbye cut-through the existing stopping be knocked out.[8] At the time of the explosion the longwall was adjacent to 20 cut-through. The explosion proof stopping at 21 cut-through had not been built and the stopping at 19 cut-through was still in place. The ventilation of LW1 was at a transition point that occurs every 100 m as the wall passes each cut-through in the tailgate return. Further discussion of this point can be found in the next section which discusses the mine ventilation system.

From the above, it can be seen that Blakefield South Mine had a convergence of factors leading up to the explosion that set it aside from other mines in NSW. Those factors were the 11 kV power supply to the tailgate, the push/pull ventilation system, the length of the longwall face, and no other underground mine was working the Blakefield South seam. Each of these factors required significantly different engineering solutions not previously encountered.

In relation to the cause of the explosion, these factors of themselves were not necessarily linked to the explosion, but compelled the investigation to look closely at each of them.

[7] Blakefield Mine Longwall Shift Production Reports for 4 January 2011.
[8] Record of Interview, 18 April 2011, 17 Q 114-134.

Blakefield South Mine Ventilation

Figure 5: No 1 shaft fan installation[9]

Overview of the ventilation

At the time of the explosion Bulga Underground Operations had deployed a forcing/exhaust ventilation system (push/pull ventilation system) for Blakefield South Mine.

In their Clause 88 approval under the *Coal Mine Health and Safety Regulation 2006* Bulga Underground Operations identified that the potential for leakage through to the surface was a possibility in the geological conditions that existed above the Blakefield seam. A further consideration in the planning of the mine's ventilation system was that the Whybrow seam above the Blakefield seam had already been extracted and between the Whybrow seam and the Blakefield seam three other seams existed: the Whynot seam, the Wambo seam and the Redbank Creek seam. Consequently, any significant pressure difference between the surface and the working face of the longwall would have a tendency to draw oxygen rich air into the goaf either from the surface or from the workings above. In either case, the possibility of spontaneous combustion occurring in the goaf material made up of those seams lying above the Blakefield seam is heightened.[10]

At Blakefield South Mine air was forced down Ventilation Shaft No 1 into the mine, while at the same time, air is exhausted from the mine via Ventilation Shaft No 2. The mine has in

[9] Beltana Blakefield South, Coal and Gas outburst Seminar, 1 December 2010, 9.
[10] Blakefield South Mine, Submissions to the Department of Trade and Investment, Regional Infrastructure and Services under Clause 88 of the *Coal Mine Health and Safety Regulation 2006,* 8 May 2009.

place two sets of double doors at the base of the men and materials drift and a third set of doors and conveyor belt seals on the conveyor belt road at the entrance to the mine—all doors are closed when the push/pull ventilation is in place creating an air lock at each of these locations.

Figure 6 is a plan of the mine's ventilation system showing the position of all relevant ventilation infrastructure. Note that the return airways are drawn in red ink and the intake airways are drawn in blue ink. The red lines marked in the roadways indicate the second means of egress out of the mine.

Intake air enters the longwall gate-roads via headings 'B' and 'C' in the maingate and heading 'A' in the tailgate with approximately 198 m^3 of air entering the longwall panel. At 9 cut-through in the maingate the intake air from headings 'B' and 'C' connects across to heading 'A' and splits; with approximately 30 m^3 directed back to the mains return and 30m^3 being directed inbye toward the sump located at 42-48 cut-throughs. A total of 114 m^3 enters the hazardous zone of LW1 with approximately 50 m^3 passing across the longwall face and the remainder ventilating the sump and the goaf edge around the full perimeter of the longwall goaf.

There is approximately 45 m^3 of air entering heading 'A' in the tailgate which joins the air coming off the longwall face at the first open cut-through adjacent to the longwall face, which then flows across that cut-through (which in the case of the day of the explosion was 20 cut-through) into heading B where it joins the air that is travelling from the sump and the back of the goaf—at this point there is approximately 140 m^3 of air. Approximately 164 m^3 then passes at the regulator in heading B in the tailgate. The discrepancy between the volume at 20 cut-through and the regulator may be generally ascribed to leakage across the stoppings' between headings A and B and the accuracy of the reading of air velocity at each point.[11]

Figure 8 shows the ventilation and air volumes that are delivered to the longwall. Note that the volumes are similar to a conventional exhaust only ventilation system.[12]

Ventilation at the time of the incident

The tailgate area of LW1 at the time of the incident was aligned with 20 cut-through. The goaf behind the wall had fallen to the back of the chocks and the goaf edge angled back approximately 10 to 15 metres to the rib of the pillar between heading 'A' and heading 'B' toward 21 cut-through.

The deputy spoke with investigators about the conditions at the tailgate about three hours before the explosion where he described roof conditions as "good".

"There was a slight crack in the floor, approximately five metres from the face line, maybe a little bit of floor heave. Only minimal, which is something I did notice, and that'd be due to the fact that we were down from (day) shift."

"Roof conditions looked good. Walked up the road, link locks were holding fine. There was no work happening out there so things were all good."

[11] Record of Interview, 17 October 2011.
[12] Record of Interview, 12 October 2011.

Figure 7 shows the goaf edge tapering back to the far rib as described by the deputy. Since the goaf has not fallen right up to the intersection the area marked on Figure 7 would not be directly ventilated and there was a possibility of methane building up in that area.

The position of the longwall adjacent to the cut-through is crucial as well. At this time in the mining sequence 19 cut-through should be open and 21 cut-through should be sealed. This had not occurred as described by the deputy on the nightshift panel before the incident.

The nightshift deputy told investigators that 21 cut-through was open and access to that cut-through was not accessible as high methane levels were over 5%.

When asked if any work has started on building that seal he said he thought some preparation work had occurred.

When a cut-through is passed by the longwall, contractors are brought in to put up the stoppings. Temporary stoppings are built first before the main seal is built, the final seal is rated at 20 psi. Blakefield South Mine had had near record production in the two days preceding the explosion, with the face position advancing 40 metres[13]. As detailed below from the examination of the mine ventilation data and subsequent modelling, Dr Hsin Wei Wu concludes that by not sealing 21 cut-through there was greater leakage of air into the goaf and therefore an enlarged explosive fringe on the goaf edge.

Dr Wu notes in conclusion that:

> *"Leaving the 21 cut-through open has allowed more air to pass across the goaf parallel to the face and behind the chocks. This created a situation of increased oxygen availability that assisted goaf gas burning during the January 2011 incident. It would appear that it would have been advantageous (and reduced oxygen availability to combustion incidents in the goaf at the LW TG end) to have had a procedure in place that meant that 21 cut-through was sealed off as soon as the LW face line reached 20 cut-through at which time 20 cut-through was opened by unsealing.*
>
> *A general recommendation pertaining to this particular situation with an active TG with two available headings only one cut-through should be open and unsealed in the Zone around the intersection of the longwall face and the TG. The opening of a specific seal should occur from when the cut-through is in line with the LW face and lasts for the period of LW face advance of no more than one pillar length beyond this."*[14]

It is worth noting from the first deputy's account that there was, after the first apparent blast, further rumbling far away in the goaf. It is a matter of speculation as to what this was as it is not picked up in any of the mine's monitoring systems but it does suggest that there may have been further explosions of methane up high in the goaf behind LW1. If this is so, it suggests that oxygen had been available in the goaf area to support the combustion of the methane.

[13] Blakefield South Mine, Deputies Production Reports, 3 and 4 January 2011.
[14] Dr Hsin We Wu, Effects of TG 21ct A-B Hdg open or closed while LW face was at 20ct, 14 March 2012, 2-3.

This oxygen may have been available via the mechanism described by Dr Wu or it is possible that the goaf had connected through to old workings in the Whybrow seam and, consequently, with the surface. This is discussed further in the sections dealing with spontaneous combustion as a possible source of ignition.

Stone dusting

Coal dust explosions are one of the greatest associated risks with the advent of a methane explosion. Limestone dust or stone dust as it is known colloquially is used in underground coal mines to control this risk. The legislation requires all underground coal mines to dust the mine roadways with limestone dust. The purpose of this is to reduce the amount of combustible material available to prevent the propagation of a coal dust explosion.

Clauses 96 to 101 of the CMHSR further set out the testing and compliance measures necessary to ensure that the above provisions are met. The permitted type of dust, limestone dust, is set out in the NSW Government Gazette no 42, page 1804, 16 March 2007.

Experiments conducted in the United States in the late 1930s by the United States Bureau of Mines (USBM) confirmed that mixtures of coal dust and stone dust having an incombustible content of over 64% would not support ignition.[15] Hence the application of stone dust to underground coal mine roadways has been part of managing the risk of coal dust explosions in underground coal mines for many years.

Stone dust acts in a number of ways to prevent the propagation of a coal dust explosion after the advent of a methane explosion. The stone dust that is used is required to be finer than 250 micrometres so that when the shock wave of a methane explosion passes through the roadway the stone dust is raised in suspension in the roadway. As the limestone is incombustible it will not support the further initiation of the explosion. The limestone also has the added benefit of decomposing when heat is applied releasing carbon dioxide as a by-product. The limestone also acts as a heat sink for the explosion further depowering the potential energy of the conflagration. The stone dust will not stop the further propagation of a methane or other type of gas explosion if the fuel i.e. methane or other gas, is still present and there is available oxygen. It will, however, effectively halt a coal dust explosion from progressing or commencing.[16]

Stone dusting at Blakefield South Mine

Records held by the department documenting testing of the stone dust from Blakefield South Mine conducted by the department show that the requirements of the legislation had in all circumstances been met and, in fact, were above minimum requirements. In fact the stone dusting standards at Blakefield South Mine were of a very high standard with

[15] Michael J Sapko 'et al', 'A Centennial of Mine Explosion Prevention Research'(2010) <http://www.cdc.gov/niosh/mining/pubs/pubreference/outputid3429.htm>
[16] CK Mann, KA Teacoach, 'How does limestone rock dust prevent coal dust explosions in coal mines' (September 2009) <www.cdc.gov/niosh/mining/pubs/pdfs/hdlrdp.pdf>

the incombustible matter in all testing from July 2010 to December 2010 being above 90%.[17]

Results of testing of dust samples taken as part of the investigation in the tailgate and maingate of LW1 after the explosion were consistent with the results of testing before the incident.

In addition to stone dusting the roadways clause 95 of the CMHSR requires stone dust barriers to be established in belt headings and the face zones (an area within 200 m of the longwall face) of the mine. The previous testing of roadway dust undertaken by the department also identified that Blakefield South Mine had maintained their explosion barriers in good order.[18]

Examination of heading B of the tailgate found that a stone dust barrier between 13 cut-through and 14 cut-through in that roadway had been in place, however the plastic bags and plastic hangers (Bat Bags) that secured them to the roof had melted and fallen to the ground. This was considered indicative of the heat from the subsequent fire having melted them.

This fact, taken in conjunction with the fact that the stoppings at 13 cut-through and 14 cut-through had been found to be severely damaged when the mine had been re-entered, supports the view that the initial explosion was not of sufficient intensity to burst the bat bags and, hence, the subsequent fire was able to melt them. If, however, there was insufficient energy to burst the bat bags there should not have been sufficient energy to knock over the stoppings. Thus, it would appear from the above that the stoppings were knocked down by the subsequent explosion.

The evacuation

Evacuation of the longwall

The moment the deputy saw the flames emanating from the goaf he made the decision to evacuate. He contacted the control room on the surface and informed the control room operator of the nature of the emergency and the decision to evacuate.

The longwall crew proceeded to evacuate the mine via the main roads using their normal diesel personnel transports. Each of the crew took a compressed air breathing apparatus (CABA) unit from the CABA pod housed in the crib room. One of the crew, who was new to the industry and Blakefield South Mine, encountered a number of difficulties with the CABA units that he attempted to use. Two units were discarded and left in the crib room before a third unit was found that operated correctly. It was assumed at first that these difficulties were because of the inexperience of the person concerned. However, upon re-entry of the mine and subsequent examination of the two CABA units, it was discovered that both units were faulty. (For further details regarding the issues with the CABA units see the discussion under faulty breathing apparatus).

[17] Department of Trade & Investment, records of testing of dust samples Blakefield South Mine and Beltana Highwall Mine 25 September 2002 to 14 December 2010.
[18] Department of Trade & Investment, records of testing of dust samples Blakefield South Mine and Beltana Highwall Mine 25 September 2002 to 14 December 2010.

Evacuation of the rest of the mine

The evacuation of the other units was initiated by telephone message to each unit where the person taking the call notified the crew supervisor/ deputy who then organised the evacuation. Of the three other units evacuated only one unit took its CABA units with them.

The deputy in Maingate 2 properly identified that the people under his control would require their CABA units as a matter of precaution whereas the deputies in the Mains and Maingate 3 failed to take similar action. Interviews with the workforce and the deputies involved revealed that generally the evacuation of the Mains and Maingate 3 proceeded without knowing or fully understanding the nature of the emergency.

In the circumstances that existed it was quite possible for the transports to encounter the effects of an explosion, fire or both. All three production units had to traverse the entire length of the mains drive and pass the entrance to LW1. The lack of knowledge of the extent of the problem could have easily translated into poor decisions being taken. The fact that not all of the people evacuating a mine that was on fire took their allotted breathing apparatus is evidence of this.

The use of tag boards to account for people in the mine appears to have operated smoothly, however their use is not without risk of human error leading to someone being left in the mine in an emergency such as this.

The investigation sought at the beginning to ascertain from the mine the names of all people at work at the time of the incident and all those underground at the time of the incident. To this end a s62 notice pursuant to the *Occupational Health and Safety Act 2000* was issued on 14 January 2011. The list of employees supplied by the mine included a number of people who were on leave on the day of the explosion. The list also excluded contractors who were present at the mine. It was only through the process of interviewing those that were known to be at work that day that the investigation was able to identify all those in the mine at the time of the explosion. It was also noted that one mine official reported that he was not confident that he knew where every contractor was that was in his charge.[19] Taken in isolation each of these observations as to Bulga Underground Operation's ability to know who was working where may not be of any great moment; however, taken together and in conjunction with the tag system, it sets up a situation where there could be confusion as to who is underground at the mine at any given time.

The investigation has observed the use of the tag board system over the course of the recovery of Blakefield South Mine and noted that on many occasions individuals do not take responsibility for their own tags, with tags often collected together by one person for either placement or removal from the underground tag boards. In an emergency this could easily lead to a person's tag being taken to the surface, while the person remains underground.

Since the time of the explosion, Bulga Underground Operations has introduced a new electronic system for keeping track of people arriving at the surface of the mine. At the time of writing the tag board system was still in place for those going underground at the Blakefield South Mine.

[19] Record of Interview, 15 February 2011, 95.

Examination of the potential use of personnel tracking systems would appear to be warranted in the underground coal mining context; especially in circumstances where people are entering and leaving the mine at random times.

Recovery of the mine

After the work force was evacuated the mine was sealed by closing the airlock doors at the mine entries and the doors on the fans at No1 and No2 ventilation shafts. Power was then isolated to the mine.

The Blakefield South Mine has an extensive gas drainage system and this was used to flood the mine with a combination of inert gases, Mineshield, Floxal Unit, fly ash, water and low expansion foam to extinguish the fire. The mine also began drilling boreholes from the surface to the site of the fire to both monitor the fire and to pump further inert gases, water, low expansion foam and fly ash into the mine to extinguish the fire.

The inertisation process continued until 15 February 2011 when Bulga Underground Operations believed that the fire was extinguished. Fresh air was reintroduced into the mine and the gas readings were monitored during the process. It was intended that after reventilation, monitoring and assessment the next stage of the recovery would begin. But 12 hours after reintroducing air to the mine, there was a reignition of gas followed by three further explosions.

The mine was resealed and inert gases were again pumped into the mine until the oxygen level was reduced to less than 2% to ensure that any fires were extinguished and to remove the possibility of any further explosions.

Remote sealing of Longwall No 1

The mine remained sealed until 31 May 2011, when the mine was reventilated. This was achieved by remotely isolating and sealing LW1 from the rest of the mine. The remote sealing refers to the process of drilling boreholes from the surface and then pumping a non-flammable material into the mine that will flow to fill up the space in the underground roadway. Before the process of remote sealing could occur, a number of potential sealing agents had to be tested. It was decided to use a product called Rocsil (a non-flammable, two component product, intended for cavity filling, air and gas sealing and stabilisation of highly fractured strata) [20] to seal those roadways. Rocsil has the advantage of being easily breached should the sealed area need to be re-entered.

Fly ash was used to seal roadways such as heading 'C' in the maingate where the conveyor belt was installed.

Holes were drilled from the surface to intersect with the LW1 gateroads between 15 cut-through and 8 cut-through in the tailgate and 16 cut-through and 10 cut-through in the maingate to create a double seal that separated the longwall, the seat of the fire and goaf area from the rest of the mine.

[20] Wilson Mining Services, Rocsil Foam Rapid Cavity Filler, 9 March 2011. <http://www.wilsonmining.com.au/Rocsil.htm>.

This allowed the rest of the mine to be reventilated. Once the atmosphere exiting the mine via No.2 fan shaft had returned to normal atmospheric levels of oxygen, carbon dioxide and nitrogen and the level of methane was below 2% the mine was re-entered through the airlock doors at the bottom of the drift.

Re-entry of Longwall No 1

Once the main body of the mine was ventilated and inspected the task of breaching the remote seals began to attempt access of LW1. The process of breaching the seals was a far more complex and time consuming task than re-entering the main body of the mine. Further seals were built outbye of the remote seals with doors that allowed for access of the Mines Rescue teams. This process created an airlock which was then purged with nitrogen. When the oxygen in the air lock was displaced and had dropped below a level that could support combustion, the mine inbye the air lock was entered and the inbye seal would be breached. Once breached and inspected a further seal would be built inbye and the process repeated.

Bulga Underground Operations has accessed and reventilated the Maingate 1 panel roadways of the mine up to the sump installations at 44 cut-through. The longwall is sealed at 18 cut-through in the maingate with all the machinery and infrastructure still in place. Access to the tailgate via maingate roadways behind LW1 goaf has been blocked by seals at 38 cut-through and 39 cut-through between 3 cut-through and 2 cut-through in the longwall take-off road. The tailgate has been reventilated to 14 cut-through, with access to the tailgate of LW1 sealed in headings A and B between 14 cut-through and 15 cut-through. The longwall face itself was accessed by the Mines Rescue teams. LW1 has not been re-ventilated.

Once the ventilation was restored to the sump behind LW1 Blakefield South Mine decided to concentrate on the development of maingate 2 to form up the face road for Longwall 2 (LW2). Installation of a new longwall has begun in LW2.

Figure 9 shows the remote seals and various boreholes to monitor conditions at Blakefield South Mine.

Electrical installations

Robert Cameron of National Personnel Group was engaged to examine the electrical installations and report if there were any issues with the reticulation of electricity into the mine that may have had some connection with the explosion.

Mr Cameron found no evidence of heat damage or arcing in any of the electrical apparatus inspected. Mr Cameron's inspections included the transformers, junction boxes, isolation points and cables supplying LW1. Mr Cameron was not able to inspect LW1 face installations. Mr Cameron was able to confirm that power was isolated to LW1 AFC tailgate motor, the shearer and stage loader. Power was not isolated to the longwall chocks, lights or direct access communication (DAC) system.

Part of the investigation included an analysis of the Citect monitoring system by Inspector Gittins. Mr Gittins noted in his report that there was no evidence within the data that showed any sign of electrical surge at the time of the incident that may be attributable to

either lightning or a surge from the supply authority. It should be noted that the Citect monitoring system at Blakefield South Mine was not designed to monitor power surges; rather, such surges may cause uncertain results or power trips which in turn may indicate the presence of such surges. The lack of evidence in this case should not be interpreted as conclusive evidence that an electrical surge did not occur. The analysis of the Citect data also supported the observation that power was isolated as stated above.[21] Taken in conjunction with Mr Cameron's inspection, a number of possible electrical sources of ignition have been rendered unlikely.

Ventilation appliances

Examination of the ventilation of the mine as it was reopened revealed that damage to ventilation structures was generally limited to the tailgate roadways. From 11 cut-through in heading 'A' of the tailgate roadway, signs of the explosion and the subsequent fire could be found in the stopping's between headings 'A' and 'B'. At 13 cut-through and 14 cut-through the stoppings were blown down toward heading 'B' and there were visible signs of scorching of the wooden upright supports of the stoppings.

In heading 'B' of the tailgate from 14 cut-through outbye there were further signs of both the fire and the explosion. The clearest signs of an explosion were the blown out stoppings as shown below.

Figure 10: 14 cut-through in the tailgate with stopping blown out
Photograph by Tim Flowers 7 September 2011

Apart from the damage that was present in the tailgate roadways there was limited damage in the rest of LW1. Inspections of the rest of the maingate roadways and those connecting the maingate to the tailgate behind the longwall revealed extensive damage to the double doors at 38 cut-through between heading 'A' and heading 'B' in the maingate which is shown below. The double doors did not appear to have been damaged by the impact of machinery or any other solid object and were believed to be in good order before the explosion. The doors are at the end of a straight roadway that would magnify the shock loading of any blast coming down that roadway.[22] There is no way of telling if the damage to these doors was from the first explosion or from the subsequent explosions during the first attempt at reventilation of Blakefield South Mine.

Not far from the double doors at 38 cut-through was another set of double doors in heading 'C' of the maingate between 38 cut-through and 39 cut-through. These doors were open when examined at the time of re-entry and it could not be conclusively

[21] Bernard Gittins, Blakefield South, Explosion and Mine Fire Investigation Analysis of Citect SCADA, 10 February 2012, 4.
[22] Dr Hsin We Wu, 'Analysis of Blakefield South Mine Explosion' 20 February 2012, 10.

established if they had been blown open or were open before the blast. If these doors were open before the blast it would have allowed air to short circuit the sump area but should not have impacted the general efficacy of the ventilation of the longwall and therefore is not considered a factor in the explosion.[23]

Figure 11 – Double doors at 38 cut-through looking from heading 'A' to heading 'B'
Photograph by Tim Flowers 14 December 2011

[23] Dr Hsin We Wu, 'Analysis of Blakefield South Mine Explosion' 20 February 2012, 10.

Exhibits and samples taken

A number of items were collected from heading 'B' in the tailgate that were either scorched or burnt. Four of these items, along with the control box (mimic box) from 158 chock; were examined by James Munday of J W Munday & Associates. Mr Munday is a forensic scientist specialising in fires and explosions.

The four items taken from heading 'B' in the tailgate are shown below:

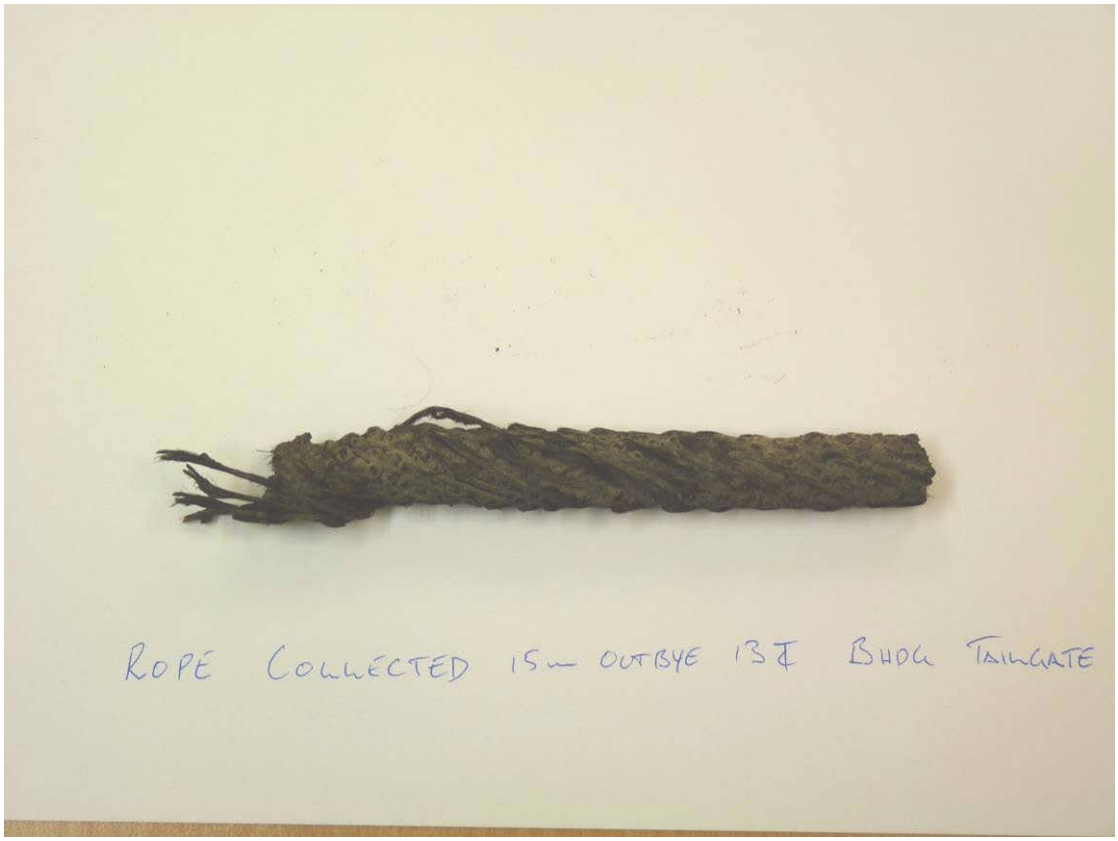

Figure 12: Sample 1 - A piece of heat-effected rope from 15 m outbye of 13 cut-through heading 'B' tailgate 1
Photograph by Tim Flowers 7 September 2011

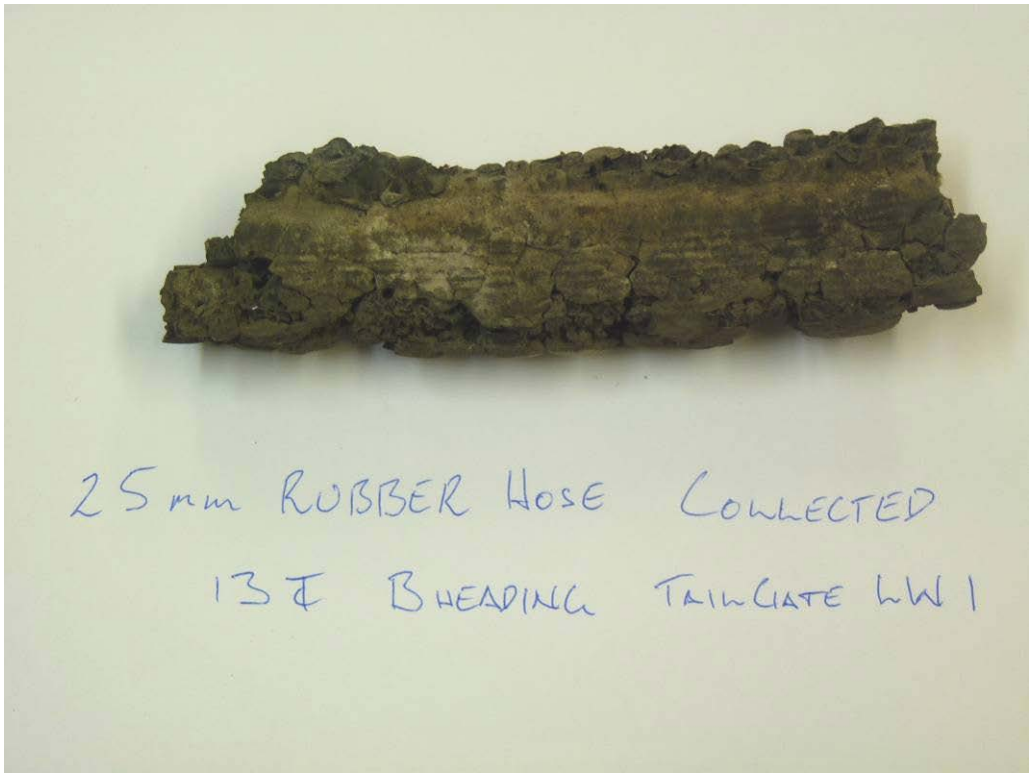

Figure 13: Sample 2 – A piece of heat-effected 25 mm hose from 13 cut-through heading 'B' tailgate 1
Photograph by Tim Flowers 7 September 2011

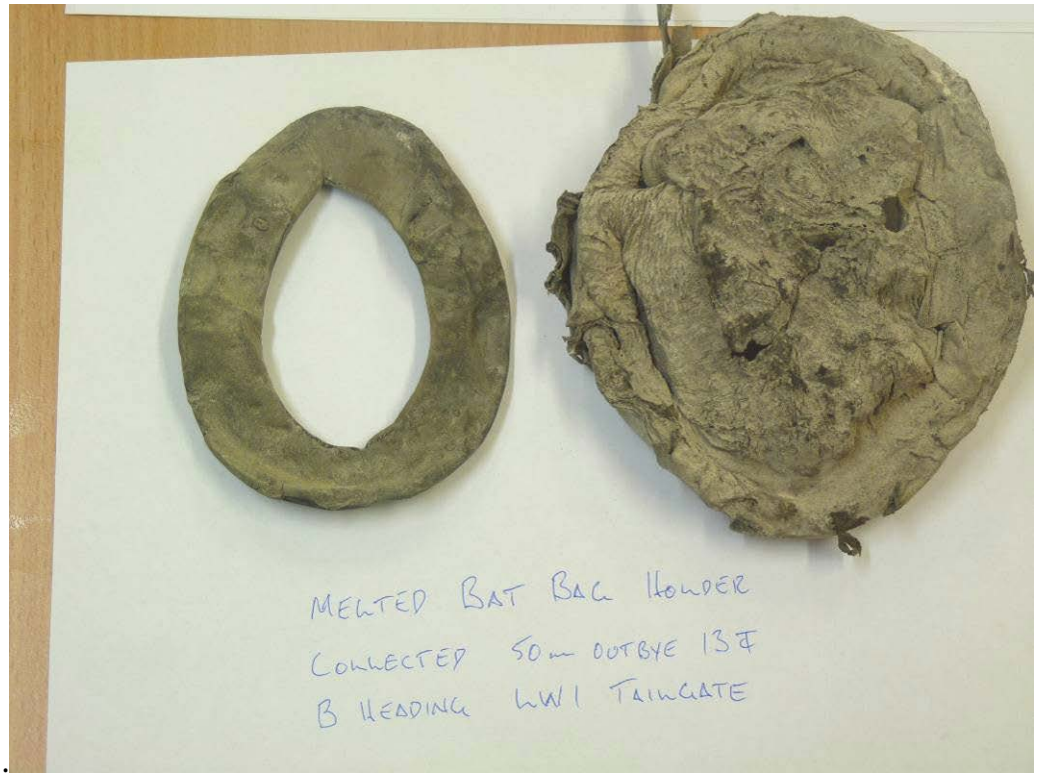

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Figure 14: Sample 3 – Heat-effected bat-bag holder from 50 m outbye of 13 cut-through heading 'B' tailgate1.
Photograph by Tim Flowers 7 September 2011

Figure 15: Sample 4 – A piece of heat-effected wood from 14 cut-through stopping Tailgate1
Photographed by Tim flowers 9 September 2011

Below is an extract of Mr Munday's report with respect to these items:

"3 EXAMINATION OF EXHIBITS

3.1 Items 1-4 were received in sealed packages from Jennie Stewart of NSW Trade & Investment and examined at our laboratory/workshop facility. The items were later returned to Ms Stewart. No destructive testing was carried out, the examinations being limited to visual and microscopic inspection under visible light. Photographs taken by investigators during initial examination showed the samples adequately and no micrographs were required.

3.2 Sample 1 – rope

This was a section of rope or similar material with a helical-stranded natural fibre outer cover and a synthetic core, probably nylon. The natural fibre was partially charred but mainly scorched and intact. The core had melted and resolidified, becoming rigid. This indicated a loss of plasticisers, consistent with prolonged heating above the softening temperature but below the auto-ignition temperature.

3.3 In my opinion the maximum temperature reached was between approximately 150°C and 300°C. There was no visible directionality to the heat

damage which could help orientate the initial flame front direction with respect to the sample.

3.4 Sample 2 – hose

The package contained three sections of double-walled rubber hose, thermally degraded and apparently pyrolysed. The hose material was brittle and friable, with directional bubbling along approximately 1/3 of the circumference consistent with off-gassing of volatiles. Because the orientation of the hose remains was not recorded at the time of recovery, I could not associate this bubbling reliably with the location of a heat source.

3.5 Sample 3 – batbag holder

This item comprised parts of a softened and rehardened polymer assembly, containing more than one polymer. The appearance indicated that high density polypropylene was probably one of the components. As with sample 1, the rigid nature indicated a loss of plasticiser consistent with prolonged heating. There was no visible burning residue, which suggested that the plastic did not reach ignition temperature or it only did so in a low-oxygen environment (below about 11%).

3.6 Sample 4 – wood

The sample comprised sections of heavy gauge timber, evenly charred through but without distinctive surface burning. This appearance is similar to that of charcoal produced by traditional pyrolysis methods. In my opinion, the most probable explanation is that the wood was in a low-oxygen environment (less than about 8%) for a period of time exceeding 2-3 days. There were no directional indicators which could orientate the wood with respect to a heat source."[24]

After the tailgate was examined the maingate roadways were examined up to 18 cut-through where the longwall was sealed. The Mines Rescue teams were able to access the longwall as far as 158 chock, take some photographs, and remove 1 item; which was a control box (Mimic box as they are known) from 158 chock. The mimic box was also supplied to Mr Munday for examination.

[24] James Munday, Report on examination of materials relating to explosion and fire at Blakefield South Coal Mine on 5 January 2011, 9 February 2012, 3-4.

Figure 16: Joy Mimic Unit IECEx TSA 06.0029X located chock 158 LW1 top of box
Photograph by Tim Flowers 24 November 2011

Figure 17: Joy Mimic Unit IECEx TSA 06.0029X located chock 158 LW1 bottom of box
Photograph by Tim Flowers 24 November 2011

The following are Mr Munday's observations with respect to the Mimic box:

> *"3.09 There was a gap along one edge where the controller appeared to have been broken away from a bracket or mounting. The clean edge showed that this occurred after the heating and I was further advised that the unit was broken away from its location on the chock by the recovery operators. Other than this, the casing remained intact with no heat penetration in either direction.*
>
> *3.10 Initial inspection of the interior through this gap showed no heat, smoke or other internal damage to the electrical components. The unit was then cut open in the presence of interested parties.*
>
> *3.11 This revealed no heat or smoke damage to the interior, no indications of dry solder joints, component failures or other localised heat sources.*
>
> *3.12 In my opinion, the controller was damaged only by exposure to external heating at relatively low temperatures (probably under 300°C)."*[25]

From the evidence collected of burnt and heat exposed materials no firm conclusions as to the source of the ignition or the site of that ignition may be drawn based on the analysis of these materials by Mr Munday:

> *"CONCLUSIONS*
>
> *5.1 Samples 1-4 had been subjected to prolonged heat exposure in a low oxygen atmosphere, but gave no directional indication to the original ignition.*
>
> *5.2 Sample 5 as seen was not a viable ignition source for a methane-air mixture, and in my view a malfunction of the controller did not cause this incident.*
>
> *5.3 I cannot eliminate electrical initiation arising from the control cables because they have not been inspected."*[26]

[25] James Munday, Report on examination of materials relating to explosion and fire at Blakefield South Coal Mine on 5 January 2011, 9 February 2012, 4.
[26] James Munday, Report on examination of materials relating to explosion and fire at Blakefield South Coal Mine on 5 January 2011, 9 February 2012, 9.

Condition of the longwall face

The examination of the LW1 face disclosed that there was no extensive damage along the face from the explosion and subsequent fire.

Figure 18: Longwall as it looked on re-entry
Photograph by S Bentham 11 October 2011

Figure 19: Looking at the goaf between the chain pillar rib and chock 1 at the main gate
Photograph by S. Bentham 11 October 2011

Figure 20 shows the conditions upon re-entry in the maingate behind the longwall.

Dust sampling

Dust samples were taken at regular intervals in the longwall gate roads as each section was made available. The results of the testing of the dust samples are not conclusive but they do indicate that the flame and heat effects of the explosions did not reach beyond 17 cut-through in the tailgate and therefore the likely point of ignition is somewhere near the tailgate of the longwall around 20 cut-through.

Sources of ignition

Spontaneous combustion

Spontaneous combustion has been the source of numerous underground fires and explosions in the history of coal mining. The fact that certain coal types may readily catch on fire by themselves is an ever present danger in underground coal mines.

The investigation has looked carefully for any sign that spontaneous combustion may have played a part in the explosion. At this time there is insufficient evidence that would allow a finding that spontaneous combustion was or was not the cause of the explosion.

What the investigation has found is that the management of spontaneous combustion was inadequate in relation to the mine's own standards.

Initially, as the investigation began there were indicators that spontaneous combustion may have played a part. At first glance there were deputies' reports that suggested the odd elevated carbon monoxide (CO) reading and readings for CO in the ventilation surveys that were in excess of the mine's Level 1 Trigger Action Response Plans. However, set against this was that general trend data coming out of the mine's monitoring system (Citect) displayed limited signs of elevated CO readings before the explosion. However, over the life of LW1 there were very limited signs of CO. The mine runs numerous diesel machines and it was put by the management that any sign of CO on the Citect system could generally be explained as the mine's normal background CO level. If this were the case Bulga Underground Operations did not establish a system of monitoring that would clearly establish this point. Therefore the cause of the earlier mentioned elevated CO readings can not be discounted as being the start of the coal in some part of the Blakefield Seam beginning to oxidise.

The description of the explosion and the fire given by the deputy raises questions with respect to the source of ignition. An explosion occurred and all the available oxygen and fuel (ie methane) may have been exhausted at the source of ignition. Therefore, at the original place of ignition there should not have been a further source of ignition if the source had been lightning; barring some sort of wick effect from another part of the goaf that was still burning available methane after the initial blast. The heat from the small explosion that took place is unlikely to have created small burning ember sufficiently hot enough to reignite the gas when the air sucked back into the lower pressure area created by the explosion.

This suggests a second source of ignition or a continuing source of ignition with sufficient retained heat to ignite the methane. This suggests a pre-existing fire as a result of spontaneous combustion.

Further, the use of timber secondary supports known as link and locks in the tailgate roads provides a source of fuel that catch fire at a lower temperature of 200 to 300 degrees Celsius; which if in contact with coal that is beginning to oxidise in the goaf may have provided the hot ember required to reignite the gas as observed by the deputy.

Bulga Underground Operations collect mine atmosphere data through three main sources: the real time monitors feeding into their Citect mine monitoring system, sampling via hand held gas detectors and bag samples taken at the goaf edge and sent for independent analysis. Bulga Underground Operations also monitors the gas in the goaf area of the longwall via a tube bundle gas monitoring system associated with the goaf gas drainage system. Bulga Underground Operations had not installed a tube bundle monitoring system (because they had been unable to identify a system that complied with Australian Standards). Figure 21 shows a plan of part of Blakefield South Mine showing mine ventilation and the location of gas monitoring sites.

Mr Gittins' report found no trends within the Citect data that would indicate any signs of spontaneous combustion in the working areas. Over the six months that LW1 had been operating, carbon monoxide levels had been generally low with no visible trends apparent. Nor were there any signs at any of the gas monitoring points that the oxygen levels prior to the explosion had fallen.

Oxygen levels at ventilation shaft fan No. 2 had been reading low at around 15.2% for a number of months, however, these readings were found to be the product of a faulty sensor. [27]

Ventilation surveys carried out at the mine on a monthly basis indicated that on several occasions carbon monoxide levels had passed the designated trigger levels of the mine without those responsible for oversight of the mine's ventilation recognising this occurrence or indeed activating the required response. During the course of interviews with the under-managers and the deputies it became apparent that they did not understand the trigger levels and how they were applied.

Figure 22 is a copy of page 12 of the December 2010 ventilation survey supplied by Blakefield South Mine under notice of 24 January 2011. The survey was conducted and recorded by an employee who had not yet been appointed as Ventilation Officer (VO). He had just gained his ventilation officer accreditation and was in the process of being appointed to that position. Bulga Underground Operations therefore did not have in place a full time VO.[28]

Note that the litres per minute of CO as calculated for TG 01 heading 'B' 19 - 20 cut-through is 25.38, the CO as parts per million is 3, and the volume of air is 141 m^3/s. There are a number of questions that are raised by these numbers. The first is that the figure of

[27] B Gittins, "Blakefield South, Explosion and Mine Fire Investigation. Analysis of Citect SCADA by Inspector B Gittins" 10 February 2012, 7.
[28] Record of Interview 17 October, 2011, page 12

25.38 L/min is above the level 1 trigger for the mine of 20 litres per minute for an active goaf (Figure 23).

Second, the reading of 3 parts per million CO is very low and approaching what, under normal circumstances, would be seen as a negligible amount of CO. It should also be noted that the reading of 3 ppm is very close to the stated + /–2ppm model accuracy the Draeger 7000 gas detector used by the VO. [29]

The stated level 1 trigger in parts per million for CO from an active goaf is 'any reading greater than 15 ppm'.[30] The air quantity of 141 m^3/s represents a very high volume of air and at that volume means that the two stated trigger levels in the Spontaneous Combustion Management Plan (SCMP) of 15 ppm or 20 litres per minute bear no relationship to each other.

When investigators questioned the anomaly, the Operations Manager, Mark Munro, the Manager of Mining Engineering Leigh Nichols and the Technical Services Manager, Miles Brown conceded that there was a problem with the setting of the trigger levels and the mine's response to them.

It should be noted that Blakefield South Mine is considered to be part of the one mining operation which also included the Beltana Highwall Mine. The management plan was adopted from the Beltana Mine and the completely different ventilation system that was in place at Blakefield South Mine was not taken into account when the plan was adopted.

Background carbon monoxide

The place at which the reading was taken was at the intersection of three air splits and was not representative of the goaf stream air alone. The measuring point captures the air flowing across the longwall, the air flowing around the perimeter of the longwall block and the air that is split up heading 'A' of the tailgate returning via the last cut-through prior to the longwall face down heading 'B'.

At any given time there may be a number of diesel machines working in the intake airways that are part of the longwall splits. Diesel machines working in underground coal mines are required under the *Coal Mine Health and Safety Regulation 2006* to meet stringent emission standards for CO. These machines are independently tested under this legislation and Bulga Underground Operations' machines generally met this standard. In any given production area at Blakefield South Mine it is likely that both men and material transports along with a variety of load haul dump (LHD) vehicles will be operating. While the machines meet the required emission standards for CO, that is not to say that there is no CO produced when they are operating. All diesel engines that are to work in an underground coal mine in NSW are limited to emission standards under the *Coal Mine Health and Safety Regulation 2006* and the NSW Department of Primary Industries Guidelines for the Management of Diesel Engine Pollutants in Underground Environments. [31]

[29] www.draegar.com/AU/en/

[30] Blakefield South Mine, Spontaneous Combustion Plan,

[31] NSW Department of Primary Industries, "Guidelines for the Management of Diesel Engine Pollutants in Underground Environments" April 2008, 29.

All diesel engines are required to be tested monthly on site to ensure the standards above are met and once every six months by an independent testing facility to ensure compliance.[32] Consequently, there will be a variable background reading for CO present in any sampling of the mine's air depending on the number of machines operating within that ventilation split.

The ventilation officers for the mine, when questioned about their knowledge of the diesel machines operating in the ventilation split that they were conducting the survey in, were unable to say how many machines and what their levels of emissions were at the time that they were conducting their surveys. In particular, when questioned with respect to readings taken in LW1 tailgate heading 'B', it was clear that it would be impossible for the ventilation officer - given the lack of communication with the rest of the panel and the distances involved - to have knowledge of the number and type of machines operating in the ventilation split when they took that reading.

Consequently it was impossible for anyone interpreting the data collected in the monthly ventilation surveys to determine what those variable background levels of CO were. Hence it is impossible for Bulga Underground Operations to properly monitor trends in the CO and therefore identify the early signs of any possible spontaneous combustion event.

The following extract is from an interview with the deputy who was in charge of a crew working in heading 'A' of TG1 on the day shift before the explosion.

He told investigators he had a quick look at the goaf edge when he was crossing through into 20 cut-through.

"I spoke to (another) deputy … I asked him how things were going with him and he said 'Good'. I asked him about the gas levels in there and he said 'Fine, no major dramas' and he asked about me and I told him the same thing."

The first deputy said he was carrying a Draeger (constant monitoring machine) with him that alarmed when he turned the corner so he stopped to check the reading. He couldn't remember the exact reading but recalled the highest CH4 reading all day was 1.3% He also recalled the carbon monoxide levels.

"It fluctuated between 2 and 4, 1 and 4 parts per million. The reason it fluctuates is I had two Eimcos working in the return area and they were both going. I suppose that's when it hit 4 parts per million but when there was only one running it was somewhere between 1 and 2 parts per million."

The deputy said he was outbye of the Eimco when he got the 4 reading, so the Draeger also captured the fumes from the Eimco. And he also recalled there were a couple of other machines driving into A heading.

All of the above technical information has been supplied to Gillies Wu Mining Technology Ventilation Consultants for analysis and it is their view that there is no evidence that would support the view that the ignition was due to spontaneous combustion. The report by Dr

[32] NSW Department of Primary Industries, "Guidelines for the Management of Diesel Engine Pollutants in Underground Environments" April 2008 36.

Wu notes that the mine monitoring overall shows that the CO rarely rose above 4 ppm and only once for a very short period hit 6ppm. [33]

Lightning

On the afternoon of the incident a thunderstorm had descended over the mine. There was severe lightning and heavy rain. Eye witness accounts put the time of the storm as being at exactly the same time as the explosion. Data on the lightning strikes was sought from a number of sources including the mine, the electricity authority and independent monitoring services.

Lightning data was supplied by Kattron and GPATS. The mine's surface electrical and gas drainage infrastructure was inspected by investigator Mark Freeman and electrical inspector John Waudby on 20 January 2011. The investigating officers were looking for any signs of lightning strike in the vicinity of the various gas drainage and electrical infrastructure and at the compliance of that infrastructure with general earthing standards and lightning protection.

No evidence was found of any lightning strike near any of the infrastructure however signs of possible lightning strike were found on trees in adjacent paddocks to the gas drainage sites and electrical installations. It is impossible to say when the damage to the trees was sustained or if the damage was caused by lightning, it does suggest that lightning strikes to earth have occurred in the vicinity. It was noted in a number of interviews with electrical staff of the mine that the power to the mine had been cut by lightning strikes on numerous occasions, and on the night of the explosion it was expected that at some point the power would drop out.

[33] Dr Hsin Wei Wu, 'Analysis of Blakefield South Mine Explosion' 20 February 2012, 10.

Figure 24 - Tree showing evidence of a lightning strike

A mine electrician who was on the surface at the time of the explosion and the storm recalled a lot of lightning strikes before the incident and one particularly close strike that shook their crib room. He told investigators that he and his colleagues had commented that there had not been a power outage.

"We've been there before and (had) lightning. Sometimes (power) goes off, sometimes it doesn't go off, but it was a fairly severe lightning sort of storm."

The electrician reported that while he could see the light from the kitchen window he was unable to see where the lightning struck. He remembered that he became aware of the incident a short time after the powerful lightning strike.

"(We) felt our crib room shake … and as we saw the light (when) the bang hit so we knew that it was very close.

The men had been trying to get through their lunch, expecting the power to go out and had been looking at the Bureau of Meteorology site that showed a weather radar with the storm cell overhead.

"It was coming over Broke, which is heading in our path," the electrician said. "If it's a large storm we will probably monitor it. There's no point putting the power back on straightaway if it's going to go back off and it's dangerous to go up to a switch yard so if it's passing we'll wait a few minutes and see what happens. And generally we get permission off the Undermanager whether they want power back on."

The observations were supported by other people on the surface at the time of the incident.

"I was working on the Citect system in the control room on afternoon shift," the control room operator told investigators. "There was a lot of lightening around but it was a long way off. I saw a flash that was closer than the others that looked to me to be at 45 degree angle from where I was sitting.

"When I looked it appeared to be an extended series of strikes travelling downwards. Within milliseconds the muster area lit up with a blue light, similar to a camera flash.

"I heard a large clap of thunder, which shook the building. I immediately went to Citect to check that everything was okay. I noticed two gas guards had alarmed at 50 ppm CO."

Further interviews of people on the surface at the time of the incident confirmed that there had been a substantial lightning strike just before or simultaneous to the incident.

The investigation engaged Tony Gillespie of Gillespie Power consultancy to examine Blakefield South Mine's electrical installations and lightning protection and to consider whether lightning was the source of the ignition.

The report has examined various means by which electrical energy, either induced or direct, may be coupled into the underground goaf or tailgate area of the longwall by lightning. These include direct paths from the surface such as telephone cables and electrical cables and indirect paths such continuous lengths of conductors left in the mine and accessing the goaf.

The report could not determine whether lightning was the cause of ignition in Blakefield South Mine. However, the report does highlight a number of deficiencies with the lightning protection and earthing installed in the surface high voltage electrical installations.

The reports of both Mr Gillespie and Mr Gittins disclose major concerns with the lack of separation between the mine earth and the incoming 66 kV supply earth along with a number of other issues.

Figure 25 – Photograph showing UGOH pole and earthing wires. Note that the overhead high tension earth is connected to the 11 kV earth.
Photograph by Tim Flowers, 31 January 2011

Figure 26: Junction box and entry point for LW1 11 kV cable entering Blakefield South Mine. Note: the installation is not fenced and cable leading into the junction box is unprotected.
Photograph by Inspector Tim Flowers 31 January 2011

Figure 27: Break in cable tray showing lack of earth bonding
Photograph by Inspector Tim Flowers 31 January 2011

Figure 28 – High tension cable join showing poor quality join
Photograph by Inspector Tim Flowers 31 January 2011

Not withstanding the concerns outlined above it would appear unlikely that the main 11 kV power supply to LW1 was a source of direct coupling into the mine. At the time of the explosion, and for some time leading up to the explosion, the LW1 crew had the power to the AFC, the shearer and the crusher isolated. The method of isolation was via a high integrity isolation unit. This device is on the stage loader and is a full mechanical separation of the power supply while maintaining the continuity of the earthing. Thus the earth would be continuous to the tailgate drive.

All cables into the LW1 were examined by Robert Cameron of National Personnel Group. No evidence of lightning flashover or burns was discovered in any of the cables, electrical installations or other continuous metal structures.

The state of electrical infrastructure was found to be of a high order generally, with the possible exception of the power supply to the inbye pumps at 41 cut-through heading 'B' where the feeder cable was reduced in conductor size via a back to back restrained coupler. The circuit breaker appeared to be adjusted to suit the 425 amp outlet, which was too high for the reduced conductor size, but the electronic overload setting of the pump was not determined. Incorrect protection setting could create a risk of fire in the cable without appropriate shutdown of power and warning of a dangerous condition. As this pump and power supply were some 1.8 km from the probable ignition point and showed no sign of damage otherwise, this installation while – not a source of ignition for the explosion – is of concern given the electrical practice observed if the overload had not been set electronically.

It should be noted from Inspector Gittins' report on the lightning protection that a lack of evidence of damage to electrical equipment does not eliminate the possibility of the dangerous effects of lightning entering the mine via this source.

However, given that the longwall chocks and equipment probably provide a very effective earth; if lightning was the cause of the explosion, it is probable that current from lightning entered the mine via some other path.

Coupling of lightning and the underground workings via a borehole

It is the view of Inspector Gittins and Mr Gillespie that a more likely source of coupling into the mine is via one of the boreholes drilled from the mine surface to the underground workings for the purposes of gas drainage, environmental monitoring or geological exploration.

Although the investigation looked for signs of lightning strike, it is fair to say that such an endeavour is to some extent looking for a needle in a haystack with the area covered by LW1 measuring some 144 hectares and the effects of lightning being capable of inducing currents in conductive pathways at some kilometres distance from the source of the strike.

Note also, the roof of Blakefield South Mine is fully meshed in both the maingate roads and the tailgate roads. The mesh, once it has fallen in the goaf and along the goaf edges, offers an excellent conductive pathway along the goaf edge for lightning – this may be a mechanism by which the electrical energy from the lightning may be dissipated from the base of a borehole in the goaf to a point where an explosive mixture of methane may be present. Further, while the surface soils at Blakefield South Mine have low resistivity allowing for an effective earth, the strata above the workings into which the mesh is bolted is of a higher resistivity and this may offer enough insulation for the mesh to transfer sufficient lightning energy to initiate an explosion.[34]

Figure 29 - Photo looking at the top of typical piezometer hole at Blakefield South Mine.

[34] Gillespie Tony 'Investigation into Potential Lightning Ignition Sources Blakefield South Mine' 20 February 2012, 1-13.

Photo taken by Inspector Laycock 19 August 2011

Note that the photo in figure 29 the piezometer hole (otherwise known as an environmental monitoring hole) at the surface, the piezometer is suspended in the borehole via a wire rope attached to a steel nail and insulated from earth via a polyethylene pipe. These piezometer holes extend all the way into the Blakefield seam in LW1 and as the longwall passes them, they are then cut out and the remainder of the piezometer is left in the goaf still attached to the surface piezometer infrastructure. Mr Gillespie's report identifies that the closest piezometer hole is some 400 metres from where the major ignition point is thought to be from the eye witness accounts. However, this does not preclude the possibility that at the time of the incident an explosive fringe may have extended across the back of the longwall in to the goaf to a point adjacent to where this borehole entered the mine.[35] Figure 30 shows the location of the piezometer holes with respect to LW1.

The surface installations for the gas drainage system in the mine were extensively examined for both their lightning protection and their earthing. The Gillespie report notes that none of the gas drainage installations had lightning mast but the installations were earthed and that the high wire fences around them would have, in all probability, acted as a lightning mast. The mines gas drainage is divided into two areas: pre-drainage surface to in-seam (SIS) holes and post-drainage (SB) holes.

The construction of the SIS holes consists generally of steel casing at the top of the hole down to a level where the hole bends to follow the seam (see Figure 31). At this point the casing changes to polyethylene in the seam. There are some above seam holes that maintain the steel casing for the entire length of the hole. However, in both cases it appears unlikely that that these holes would provide a pathway for stray current into the mine. In the case of the in seam holes using the polyethylene, the polyethylene will not conduct a current. In the case of the above seam holes while the casing may be sitting above the seam it may connect into the mine atmosphere where the hole enters the area above the extracted area of the longwall. However, since the metal casing is in contact with the strata there should be a plausible earth for any stray current.[36]

The post drainage holes are vertical holes accessing the goaf. These holes are cased from the surface with steel casing to a point approximately 10 metres above the seam, at which the casing is changed to fibreglass to allow the shearer to cut-through as the longwall advances past the hole. Once the goaf falls, depending on the height to which it falls, it is possible for the base of the steel casing to be connected to the mine's atmosphere via the goaf. Once again, the steel casing is not insulated from the ground and is therefore very effectively earthed. This should dissipate any stray current well before it can reach the base of the casing and arc to some other conductor or earth in a hazardous part of the goaf or mine.

Conductive pathways through indirect coupling

The possibility that a current may be induced in a disused cable some hundreds of metres underground has been recognised for some time, and given further validity by the Sago investigation conducted by the United States Department of Labour Mine Safety and

[35] Dr Hsin Wei Wu, 'Analysis of Blakefield South Mine Explosion' 20 February 2012, 22

[36] Gillespie,Tony 'Investigation into Potential Lightning Ignition Sources Blakefield South Mine' 20 February 2012, 15

Health Administration Coal Mine Safety and Health (MSHA). The Sago underground coalmine located in West Virginia, United States of America, had an explosion underground on 2 January 2006 which claimed the lives of 12 mine workers. The MSHA investigation at Sago Mine examined closely the various methods that stray electrical energy generated and induced by lightning may find its way into hazardous areas of the mine. Specifically, modelling of transfer functions for lightning coupling into the Sago Mine were undertaken and formed part of the MSHA report.[37]

As a result of the publication of the report into the Sago explosion (dated 9 May 2007) the underground coal industry became aware of the possibility that conductive materials left in the mine workings may have the capacity to carry a voltage induced by lightning or other high voltage installations into a hazardous zone in a mine.

Bulga Underground Operations, as part of their general operation as the longwall retreats, requires the removal of all cabling and other general infrastructure. However, the requirement to remove all conductive pathways leading to the goaf as part of a general strategy to remove the risk of coupling of stray electric currents into the goaf is not required as part of their Electrical Engineering Management Plan or their Fire and Explosion Management Plan. It would appear from the interviews conducted that, generally, the removal of larger cables and other infrastructure is undertaken to recover costs, not to ensure the safety of the mine. Interviews have also suggested that 100 m lengths of telephone line and possibly lengths of conveyor belt signal line have been left in the tailgate roadways of LW1.

Interviews conducted with the mine deputies and the manager of electrical engineering confirms this view:

The Manager of Electrical Engineering told Mr Gittins he was not aware of any mine policy concerning the removal of disused cable that might otherwise end up in the goaf. He said it was normal to recover all of the larger electrical cables, punt cables and distribution cables, for their economic value.

Because cables were progressively cut as the work advanced, there were short lengths of about 100 metres left behind.

The Manager of Electrical Engineering said there were “a lot of different theories” about leaving cable in the goaf.

“Well I suppose, the couple of chucks, you're alluding to the Sago stuff, which to my knowledge … there's a lot of different theories out there. There's a lot of recommendations … some of them vague, some of them practical, some of them impractical. To my knowledge there's been no process to filter out and identify what's fact, what's fiction.”

The response from the manager indicates that he, and therefore the mine (due to his influence as manager of electrical engineering), did not consider the Sago findings sufficiently reliable to induce them to take what, in essence, are minor safety precautions.

[37] United States Department of Labor Mine Safety and Health Administration Coal Mine Safety and Health, ‘Report of Investigation Fatal Underground Mine Explosion January 2, 2006 Sago Mine Wolf Run Mining Company Tallmansville, Upshur County, West Virginia Id No. 46-0879, attachment DD, Measurement and Modelling of Transfer Functions for lightning coupling into the Sago Mine, 9 May 2007.

Xstrata Coal, in a written response to the department,[38] claimed that only lengths of telephone cable were left in the tailgate roadways. However, the recovery of cables was not seen as a crucial part of the safety system for the mine; and therefore recovery of cables was subject to assessment of the difficulty of task weighed against the financial benefit – not its potential safety impact.

The possibility that the source of ignition was through an induced voltage along one of the sections of cables left in the tailgate and running into the goaf remains, as noted by Mr Gillespie in his report, quite plausible.[39]

Contraband

There are a number of sources of ignition that may be introduced into the mining environment by ignorant or negligent employees, contractors or visitors. In general these sources of ignition are known as contraband and include items such as: cigarettes, tobacco, mobile phones, car keys or other electronic devices and unprotected alloys.

Bulga Underground Operations have as part of their Blakefield South Mine Safety Management Plan a systematic process for educating their workforce and visitors as to those things that they may or may not take underground. They also have in place random searches of the workforce for items of contraband.

In questioning of a number of employees and contractors of Blakefield South Mine it was clear that these searches were conducted regularly and all people questioned had been searched at various times over the past year.

As the likely point of ignition for the fire and explosion on 5 January 2011 was somewhere near or adjacent to the tailgate (not discounting the range of the explosive fringe behind the longwall on the goaf edge), questions were asked of those people who worked near or around the tailgate and return as to whether they had ever smoked underground or had ever seen anybody smoking underground or take anything into the mine that was not allowed. Not one of the 88 people formally interviewed or those that were spoken to informally had any knowledge of any such occurrence. It is fair to say that when this question was put to many of the people interviewed the idea that any person may smoke underground seemed ludicrous and clearly the message that all of the people that the investigation dealt with from the mine had taken in was, that to smoke underground was a criminal act, and to not do anything about it, if a person came across someone smoking, would be equally criminal.

It would seem more probable that some form of unapproved electrical apparatus may be taken into the mine and possibly be involved in the ignition of methane by misadventure. However as stated above, given the instructions that have been given to each person that enters the mine; that no one was actually present at the time and place of ignition; and that the most likely types of electrical items that may be taken into the mine are of a personal nature and unlikely to have been left in or about the tailgate or the return – the likelihood of an unapproved electronic device being the source of the ignition is unlikely.

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[38] Response to s62 Notice *OHSA 2000* from Xstrata Coal to Department of Industry and Investment, 10 June 2011.

[39] Gillespie,Tony 'Investigation into Potential Lightning Ignition Sources Blakefield South Mine' 20 February 2012, 22.

The investigation to date has been able to enter LW1 tailgate return airway as far as 14 cut-through and no physical evidence of any prohibited article has been observed. The Mines Rescue teams have accessed as far as 19 cut-through in the tailgate return airway, however these roadways have not been formally inspected. Similarly, the rescue teams have accessed the longwall face up to the tailgate chock (the roof having fallen in past this point) and again this part of LW1 have not been formally inspected. It is unlikely that the actual tailgate area will be available at any time in the near future for a proper forensic examination to conclusively rule out contraband as a source of ignition.

It is impossible to be absolutely certain that some form of contraband brought into the mine was not the possible source of ignition. However, from the available evidence it would seem extremely unlikely that the explosion could have occurred as the result of someone smoking and leaving a smouldering butt behind or of an electronic device such as a watch, mobile phone or car keys being the source of the ignition.

It would appear on the available evidence that Bulga Underground Operations had an effective system for controlling items being taken into Blakefield South Mine that may be capable of igniting CH4.

Further issues

Tube bundle system

At the start of the investigation it became apparent that there was an issue surrounding the use of what is known as a tube bundle system and its use in monitoring the mine atmosphere. A common form of gas detection and atmosphere monitoring used in coal mines is a system of tubes placed at strategic points within the mine from where atmosphere can be pumped to a central monitoring point on the surface where the gases are analysed.

According to Blakefield South Mine management it was the intention to have installed a tube bundle system to monitor the mine's atmosphere. At the time of the incident this system had not been installed.

According to officials of the mine there were a number of reasons why the system was not in place. The most pressing reason, being, that the supplier of the system was unable to install it to the appropriate Australian Standard AS/NZS 3000:2007 Electrical Installations. It is important to understand that the inability of the supplier, SICK Maihak, to meet this standard is not as clear-cut as it would appear. The department as regulator had indicated for coal mines in New South Wales that the gas monitoring stations that housed the pumps and the electrical monitors were to be considered a hazardous area as defined AS/NZS 3000:2007 clause 7.7 (as distinct from a hazardous zone as defined by the *Coal Mine Health and Safety Regulation 2006)* and that all such installations should be compliant with the Australian standard. Previously AS/NZS 3000:2000 had applied to these installations and the supplier mistakenly believed that they would be able to comply with the later standard.

The following is a summary of an interview with the manager of electrical engineering describing some of the issues in relation to the installation of the tube bundle system:

The manager said he became involved in the latter stages of that contract, in relation to inspection of the progress work and raising the issues list, which was sent to the Original Equipment Manufacturer (OEM) for rectification issues.

"There was a lot of discussion about their hazards area assessment and the way they were managing that," he said. "I think it's fairly well known within industry there was a fair few issues with the OEM. Not just for our mine, but other mines as well who were having equipment built there. So we progressed, we were working through the issues that we perceived with the OEM to achieve a product at the end that we thought met the legislation."

The manager said he was not aware that it was a requirement of the approvals that tube bundle monitoring systems were put in place for the operation of the longwall.

He agreed that the equipment manufacturer was unable to provide a product that was able to meet the legislative requirements.

"It was part of our contract that they had to do the hazardous area assessment and build the installation to suit the requirements of that assessment," he said. Regardless of why there was no tube bundle system in place in the mine it would appear such a system would have been invaluable in tracking gas trends within the mine at locations that would better reflect what was happening in the mine.

Bulga Underground Operations has now installed a tube bundle system in the Blakefield South Mine which purportedly meets the Australian Standard.

Spontaneous combustion management plan

There were a number of problems identified with the Spontaneous Combustion Management Plan (SCMP) for Blakefield South Mine.

In general, the mine's trigger levels were set in parts per million and litres per minute. The litres per minute figure delivers a more accurate reflection of the volume of CO in relation to the volume of air passing down the roadway. When questioned about this relationship between parts per million of CO and the volume of CO per minute, few of the deputies could explain the relationship or recall what the various trigger levels were. When the mine deputies were asked what training they had received with respect to the mines spontaneous combustion plan, it became apparent they had been made aware of the document and received training that was the same as that for the general workforce.

There also existed a disparity between the setting of CO in parts per million measured and the litres per minute when there were large air quantities at various parts of the mine, as there was at Blakefield South Mine.

Before longwall mining can start in NSW the mine is required to submit to the Department a submission known as a Clause 88 submission under the *Coal Mine Health and Safety Regulation 2006* requiring the mine to set out how it intends to conduct its mining operation. Beltana Highwall Mining as it was known made such a submission to the Department in May 2009.[40] In that submission Beltana Highwall Mining states:

[40] Letter and application from Beltana Highwall Mining Pty Limited to Minister for Primary Industries, Application under clause 88 *Coal Mine Health and Safety Act 2006*, 8 May 2006, 1-48.

"In particular the following plans have been examined and reviewed to ensure that the project complies with them in all regards and that they are suitable application in the project;

- Spontaneous Combustion Management Plan – OHSSTD3.5.08.002"

Minor modifications have been made to these plans, where required, to make them completely applicable to the conditions and circumstances at the Blakefield South Operation" [41]

According to the technical services manager prior to and subsequent to the incident the *Spontaneous Combustion Management Plan* had been reviewed before its application to Blakefield South Mine and was due for revision in April 2012. The explosion brought forward that revision as it was a designated trigger for review action. When it was put to the manager that the trigger levels had not been adapted appropriately for the Blakefield South seam it was his view that the triggers were appropriate at the goaf edge of an active goaf and this was in accordance with the SCMP.

However the level 1 trigger of 20 litres per minute is required to be measured in the general body of the return . It does not say that the measurement should be taken at the tailgate goaf edge where there is a single split of air coming across the longwall face.

In fact, the monthly ventilation survey took the measurement at a point that was in the general body of air of the return and a point at which the air volume averaged around 140 cubic metres per second. The formula to convert parts per million carbon monoxide to litres per minute, which the pro forma for the monthly ventilation survey for Blakefield South Mine had printed on the front cover, is reproduced here:

"Area:	*A = width x height - (Area of obstructions)*
Average Velocity:	*VT = (Vl + V2 + V3) -+- 3*
Quantity:	*Q = VT X A*
CH4 Flow:	*CH4 l/s = 10 x Q x % CH4*
CO Flow:	*CO l/min = 0.06 x Q x ppm CO*
I/R	*"I" indicates Intake Airway; "R" indicates Return Airway."*[42]

Figure 32: Formula printed on front cover of Blakefield South Mine monthly ventilation survey

Consequently a reading of 3 parts per million CO in an air quantity of 140 m^3/s will convert to a volume 25.2 L/m.

[41] Letter and application from Beltana Highwall Mining Pty Limited to Minister for Primary Industries, Application under clause 88 *Coal Mine Health and Safety Act 2006*, 8 May 2006, 17.
[42] Blakefield South Mine, Monthly Ventilation Report, OHSFRM3.5.08.019, 5 August 2009.

At the time of the incident, the person taking the ventilation surveys was also acting as an undermanager at Blakefield South Mine at the time of the incident[43]. He carried out the last ventilation survey before the incident in early December 2010 which is recorded as the November Monthly Ventilation Survey[44]. In his interview of 17 October 2011 he describes the location at which the reading is taken in heading 'B' in the tailgate (Figure 33).

He also observes that Bulga Underground Operations has not invoked a Level 1 response for Blakefield South Mine in accordance with the SCMP, even though the June 2010, October 2010 and November 2010 ventilation surveys taken over the six months that LW1 had been working, had identified that the Level 1 TARP had been exceeded in the tailgate in heading 'B' adjacent to the longwall face.

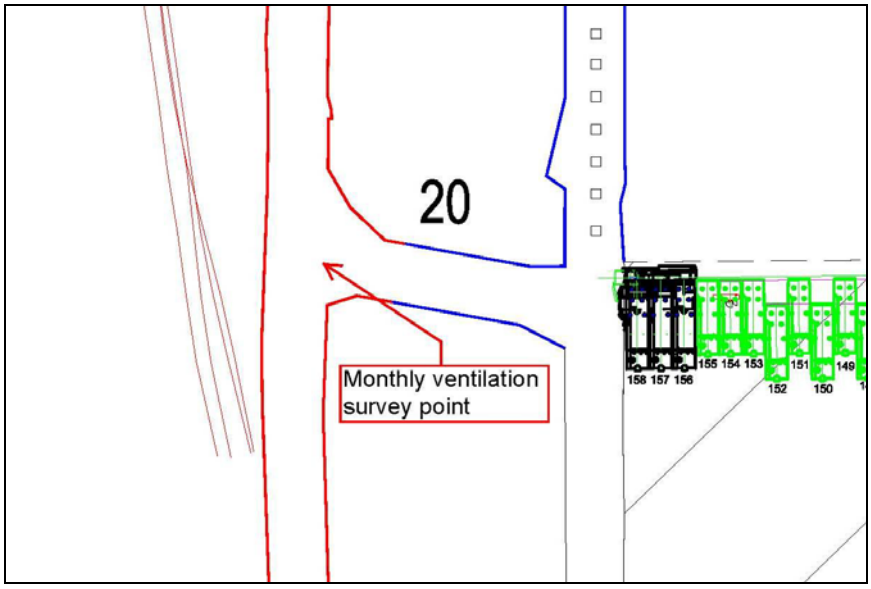

Figure 33: Location of monthly ventilation survey point

As no proper measurement was taken of the actual machines working in each district it is impossible to say what the actual source of the CO was. It was also impossible to know the normal background CO for the mine.

Another issue that came to light from the examination of Bulga Underground Operations' control of the spontaneous combustion was the lack of understanding by the deputies of the gravity of the issue with respect to the potential for an explosion.

A number of the deputies spoken to were not conversant with the conversion of parts per million CO into litres per minute. The deputies are the frontline persons in the mine who sample the mine atmosphere at regular intervals, providing a check against the accuracy of the fixed monitoring system and the capacity to take measurements in places in the mine not accessible to the fixed monitoring systems.

[43] Record of Interview, 17 October 2011, 7.
[44] Blakefield South Mine, November Monthly Ventilation Survey, 6-9 November 2010, 1-15

Investigators asked one mine deputy if he understood the difference between parts per million and litres per minute, in carbon monoxide.

"I don't fully understand it but I know there is a difference," he said.

He said that his monitor read in parts per million and he "understood" there was a calculation to transfer the reading into litres per minute "but I don't know it".

Investigators showed the LW1 deputy the December ventilation report, with a number highlighted in litres per minute for carbon monoxide.

When asked if the number meant anything to him, the deputy said "no".

An undermanager told investigators he did not know the difference between a CH4 reading in percentage and a CH4 reading in litres per second.

When deputies working at Blakefield South Mine were asked about the training they had received with respect to spontaneous combustion the answers were invariably vague and uncertain.

Bulga Underground Operations was working a seam at Blakefield South Mine that was completely new to them, and spontaneous combustion had been identified as a risk to the business.

Faulty breathing apparatus

As stated earlier in the report, two of the compressed air breathing (CABA) units, which were stored in the crib room of the longwall, failed to work properly at the time of the evacuation. An electrician upon learning of the evacuation attempted to deploy a CABA unit from the CABA pod kept in the crib room. When he attempted to use the CABA he discovered an apparent leak at the T piece and was advised by another crew member to try another unit. The electrician then attempted to use another CABA unit which also failed. The third unit he tried worked properly and the crew was able to evacuate the mine. The following is an extract of the record of interview with the electrician:

"I had a bit of trouble with my first CABA," he said. "I don't know what happened with that, but when I went to turn it on, air started coming out of the, the T piece.

He took a second unit and air started coming out of it as well.

"I got someone to check it … and I think (the deputy) said to me 'No it's stuffed. You have to get another one'. So I got another one and got into the transport and put it on there, and that was fine."

Upon re-entry of the mine both CABA units were recovered from the crib room in 18 cut-through of the Maingate .

Figure 34: Photo of the two discarded CABA units as found in the crib room
Photograph by S Bentham 11 October 2011

The units were first examined at the Mine Safety Technology Centre Thornton where it was discovered that both T pieces on the units were broken. Further examination of the fracture in each T piece was conducted by Bureau Veritas .

The Bureau Veritas report concluded that both T pieces were fractured due to "*brittle overload*" resulting from higher than normal loading.[45] This suggests that both units had at some time either been dropped or damaged during transport in and around the mine. It should be noted that the CABAs are housed in specially constructed padded containers which are designed to keep the units in good order. After the fracture in the two CABA units was communicated to Bulga Underground Operations, a follow-up examination of all of the CABA units at Blakefield South Mine revealed a further two units that were similarly fractured at the T piece. The department issued a safety alert with respect to this equipment failure. These failures in the CABA equipment are serious in that in slightly changed circumstances it may have resulted in four fatalities.

[45] S Akbari, R Metcalfe, Bureau Veritas, 'Compressed Air Breathing Apparatus T-piece Failure' 19 December 2011, 13.

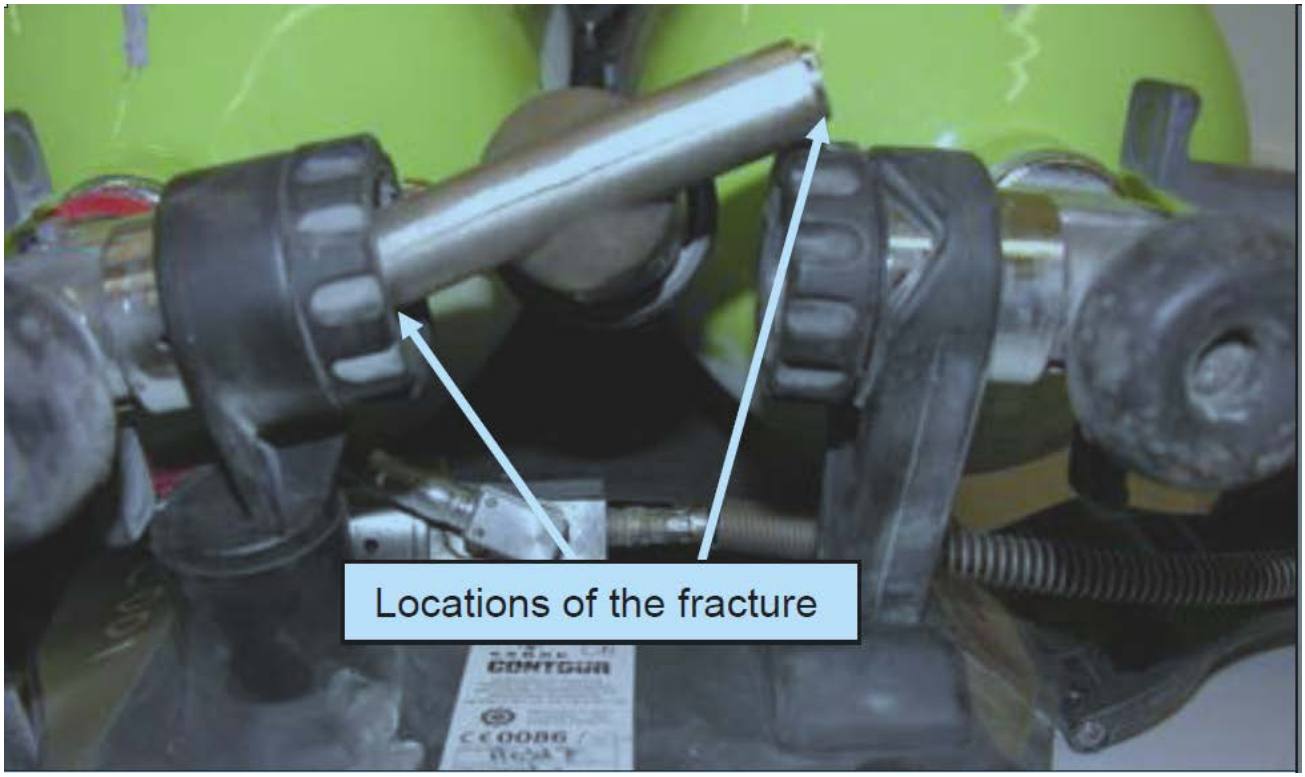

Figure 35: Photograph of fracture locations in the CABA unit[46]

Employees at risk

At the time of the explosion there were 47 employees down the mine. All were safely evacuated from the mine.

Once the explosion had taken place it was possible that a coal dust explosion could have followed in which event every person in the mine could have been killed. Beyond this any rescue attempt placed all those involved at further risk from further explosions, fire or inhalation of noxious gases.

The above does not include the risk to people on the surface of the mine if there were an ejection from the entry of the mine of any such explosion. Added is the risk to workers in recovering the mine after stabilisation of the mine atmosphere from roof fall and other activities associated with that recovery.

The seriousness of this event cannot be understated, nor can the implications for the broader underground coal mining community.

[46] S Akbari, R Metcalfe, Bureau Veritas, 'Compessed Air Breathing Apparatus T piece Failure' 19 December 2011, p5

Findings

Incident causes

This investigation has found that on Wednesday 5 January 2011 a low pressure methane explosion occurred at Blakefield South Mine somewhere in the tailgate area adjacent to 20 cut-through of LW1. A methane fire was observed subsequent to the explosion. The explosion did not propagate a coal dust explosion.

The result of this investigation into the causes and circumstances of the explosion is an open finding. It is unlikely at this stage that the exact incident cause will ever be known.

There are two plausible sources of ignition that can neither be confirmed nor eliminated: lightning strike and spontaneous combustion.

It is however, impossible to rule out all other possible sources of ignition.

Therefore the findings of this investigation must be open.

Lightning

The concurrence of a severe lightning storm and measured lightning strikes minutes before the explosion is too much of a coincidence to ignore. The fact that possible pathways for the lighting into the mine's goaf existed in the form of: gas drainage boreholes, exploration boreholes and environmental monitoring holes; and through induced currents in conductive material left behind in the mine's tailgate roads as well as other more traditional pathways such as via the mine's electrical system requires that this possible cause is highly plausible.

Spontaneous combustion

The description of the explosion and the fire begs a series of questions with respect to the source(s) of ignition. An explosion occurred and, once that had occurred all the available oxygen and fuel ie methane may have been exhausted at the source of ignition. Therefore, at the original place of ignition there should not have been a further source of ignition if the source had been lightning – barring some sort of wick effect from another part of the goaf that was still burning available methane after the initial blast. The heat from the small explosion that took place is unlikely to have created small burning ember sufficiently hot enough to reignite the gas when the air sucked back into the lower pressure area created by the explosion.

This suggests a second source of ignition or a continuing source of ignition with sufficient retained heat to ignite the methane. Having for all practical purposes removed electrical sources of ignition from the mine's infrastructure; and leaving aside mechanical and frictional sources, this brings back the question of a glowing ember from a pre-existing fire as result of spontaneous combustion.

Bulga Underground Operations could not know if a heating was developing or not – spontaneous combustion must be given serious consideration as the cause of the explosion.

Stone dusting

The methane explosion did not initiate a coal dust explosion and this must to a large extent be credited to the amount of stone dust applied at Blakefield South Mine as required by the legislation.

Safety Management Systems

It is noted that on the current Xstrata Coal website the Chief Executive Officer of Xstrata Coal, Peter Freyberg makes the following statement:

> *Since June 2008 there have been six fatalities at our operations and our overall safety performance has not improved. This is unacceptable. The safety of our people is not negotiable.* [47]

On that same website page, Xstrata promotes as part of its overall safety strategy an intervention program called Safe Coal which has as its basic tenet "*commencing every task with the certainty that it will not result in a fatality or injury to yourself or other people working in or around our operations.*"[48]

The following summation of this investigation indicates that Xstrata's Blakefield South Mine did not meet the standards set by Xstrata for their operations.

The following findings were revealed during the course of the investigation:

Electrical

- The earthing protection of the mine with respect to possible lightning strike or electrical surges was not built to design specification and may not have prevented the transfer of the dangerous effects of lightning underground as required by AS1768:2007 and AS3007.2 – 2004.
- Electrical staff responsible for the installation and maintenance of Blakefield South Mine's lightning and earthing protection had poor knowledge of these systems.
- Bulga Underground Operations failed to remove all conductive pathways leading into the goaf of Blakefield South Mine LW1 in line with the recommendations that came out of the Sago Investigation.
- Bulga Underground Operations failed to identify the risks associated with various boreholes at Blakefield South Mine connecting the surface with possibly explosive parts of the goaf and possible ingress of lightning into the mine via these sources.

Training

- Bulga Underground Operations failed to ensure that their Blakefield South Mine frontline supervisory staff (the mine deputies) were retrained in the new conditions that were to be encountered in the new seam that they were mining.

[47] Xstrata Coal (20 March 2012) <http://www.xstratacoal.com/EN/AboutUs/Pages/safecoal_approach.aspx>
[48] Ibid.

In particular it was clear that knowledge of spontaneous combustion and of the mine's Spontaneous Combustion Management Plan was less than adequate.

Systems of work

- Bulga Underground Operations did not adequately revise the Blakefield South Mine Spontaneous Combustion Management Plan when it initiated the new mine and further when it commenced LW operations in a new seam.
- Bulga Underground Operations did not properly follow or understand its own Spontaneous Combustion Management Plan.
- Bulga Underground Operations did not install an adequate gas monitoring system at Blakefield South Mine.

Emergency Management

- The inconsistent use of breathing apparatus in the evacuation of Blakefield South Mine exposed problems with emergency response training and communication regarding the nature of the emergency.
- Communication of the nature of the emergency and the required response to persons in other areas of Blakefield South Mine was less than adequate.

Auditing

Blakefield South Mine has in place what appears on the surface a robust system of audit with safety audits conducted on a regular basis both internally by the mine, and externally by the parent company Xstrata Coal Pty Limited.[49] However, these audits did not identify the failings listed above.

Positive actions by the mine

Having made the above observations on Bulga Underground Operations it must be said that Bulga Underground Operations has substantial safety management systems in place at Blakefield South Mine.

Employees interviewed throughout the investigation were generally well-informed with respect to their responsibilities as far as safety was concerned and were in receipt of regular training.

The practices and systems put in place by Bulga Underground Operations with respect to stone dusting and the control of contraband were effective.

The failings identified were systemic and not necessarily the result of any one individual's actions. The investigation found that all staff and employees generally, when they became aware of a problem, responded to correct that problem to the best of their ability.

[49] 'Record of Interview' 16 December 2011, 10.

Actions of the department

Officers of Mine Safety Operations responded to the immediate oral notification given 5 January 2011. (Darrell) John Sherrell, Inspector of Coal Mines, attended the mine just before 10pm on 5 January 2011.

The mining inspector issued the following notices:

- Investigation notice under Section 89 of the *Occupational Health and Safety Act 2000* for the non-disturbance of the longwall face and incident scene; and
- Notice under Clause 51 of the *Coal Mine Health and Safety Regulation 2006* for the longwall face to cease longwall operations and to restrict entry of persons onto the face.
- Bulga Underground Operations was notified on 13 January 2011 that a decision had been made to investigate the incident. The Investigation Unit conducted a detailed and thorough investigation into the incident.
- An investigation notice was issued under Section 89 of the *Occupational Health and Safety Act 2000* by the Investigator, Tim Flowers on 14 January 2011for the non-disturbance of the incident scene.
- Numerous subsequent s89 and s93 *Occupational Health and Safety Act 2000* notices were issued by Inspector Sherrell to ensure that each stage of the recovery of the mine was undertaken safely. (Note that extensive consultation between the department and Bulga Underground Operations was undertaken as each stage of the recovery was planned).

Mine reopens after work method reviews

Bulga Underground Operations conducted a series of information sessions, refresher training and toolbox talks for all employees on hazard recognition and process identification, in particular the TAKE 5 and job safety analysis processes.

Bulga Underground Operations reviewed their Damaging Energy Standard Operating Procedure and Longwall Orientation package. The longwall orientation package was amended and retraining was scheduled for all longwall personnel focusing on the steps of isolation and verification of the isolation.

Issues drawn to operators attention by the Investigation Unit

A number of issues were drawn to the attention of the operator of the coal operation during the course of the investigation, including:

- The mine's high voltage earthing system. Notices were issued by MSOP Electrical Inspector on 30 January 2011.
- Review procedures for the mine's evacuation in an emergency with particular reference as to when breathing apparatus ought to be accessed and used.
- Review TARP levels for the mine's spontaneous combustion management plan to reflect greater air volumes used in Blakefield South Mine.
- Review training with respect to spontaneous combustion for deputies.

- Inconsistencies with the application of the mine's isolation standards.

Safety Alerts released

As a result of the incident two safety alerts were issued:

- SA11-11 Faulty Sabre CABA units, was released to industry and published on the Department's mine safety website on 24 October 2011.[50]
- SA11-12 Ignition of gas leads to underground fire, was released to industry and published on the Department's mine safety website on 24 October 2011.[51]

Strategies to prevent recurrence

Identified hazards

There are numerous possible causes of ignition in any underground scenario and these have been, for the most part, documented. To these identified hazards, a vast array of strategies has been developed to prevent ignition of methane.

In the case of Blakefield South Mine, the implementation of the tube bundle system is essential to the future safe operation of the mine.

Potential risk

The risk of catastrophic failure in coalmines is ever present and while attention to other areas of safety should not be diminished, there is no room for error where there exists the potential for accumulation of dangerous levels of methane and the subsequent risk of explosion.

All mines that use the longwall method of mining that have methane present in the mine play a balancing act to ensure that methane in its explosive range does not accumulate in dangerous quantities within the working areas of the longwall face. In many instances there exists a line behind the chocks somewhere in the goaf where this dangerous level of gas exists. It is part of the management of the ventilation that this explosive fringe does not encroach on the face area or within a predetermined distance of electrical apparatus such as motors and switches. Bulga Underground Operations sought to achieve this outcome at Blakefield South Mine via application of the push/pull system of ventilation. This investigation has not discovered how or if this system failed. However, it is reasonable to conclude that in the circumstances the ventilation system did not keep an explosive mixture of mine atmosphere from an unknown source of ignition, or in fact the ventilation system itself was responsible for creating that source of ignition through spontaneous combustion. It is therefore incumbent upon Bulga Underground Operations and the coal mining industry if they wish to use this method of ventilation to continue to research its effectiveness and remove any doubts that may exist as to its safety.

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[50] NSW Trade & Investment, Minerals and Petroleum Division Mine Safety, (11 April 2012) <http://www.dpi.nsw.gov.au/minerals/safety/safety-alerts/safety-alerts-2011>

[51] Ibid.

Bulga Underground Operations should maintain its strict enforcement policy preventing contraband entering Blakefield South Mine. This should be an industry wide priority to reduce the risk of preventable accident or injury.

Bulga Underground Operations should continue to maintain the high standard of stone dusting found in this investigation. The broader industry should be encouraged to meet similar standards in the application of stone dust in the workings.

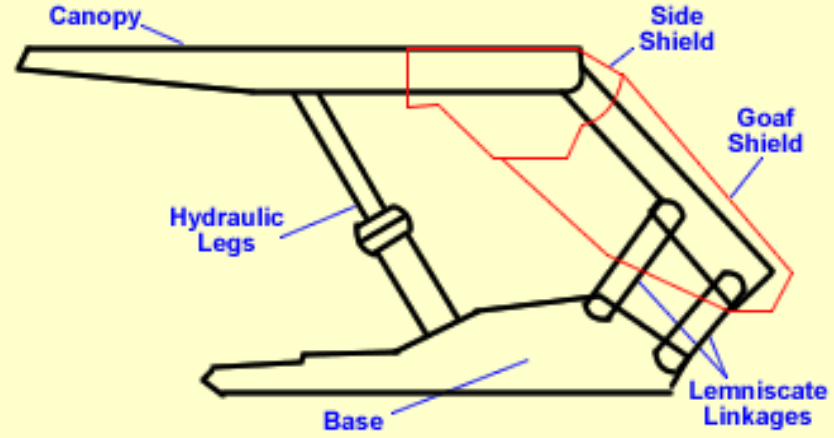
Glossary of Terms

☛ This glossary of terms is relevant to the understanding of terms used within this report and may not accurately reflect wider meaning or understanding in industry.

(the) Act	*Occupational Health and Safety Act 2000*
AFC	Armoured face conveyor  To maintain a safe working environment powered supports have to be advanced sequentially. This is achieved by utilising an articulating AFC which runs along the face with the shearer mounted on it. The AFC is made up of short sections, called pans, which allows it to "snake" along the face as the supports are progressively advanced. Each powered support is pinned into a pan. The AFC is powered by drive units located either at the Maingate or tailgate ends or at both ends.
BBRA	Broad-brush risk assessment
bi-directional cutting	Bi-directional (Bi-di) cutting is described as full web extraction of the coal seam in one pass along the longwall face, in each direction. Each time the shearer cuts from one end of the face to the other, a full web of coal is extracted.
CABA Unit	Compressed air breathing apparatus unit
caves	The purpose of the roof supports on a longwall face is not to prevent roof movement but to control it so that the immediate roof remains essentially intact where the coal is cut and within the area of the face where personnel have to work. Once the work area has moved forward it is acceptable, indeed desirable, that the roof collapses or **caves**. The ideal situation is that the roof caves immediately behind the supports as they are moved forward; if the collapse is delayed the roof strata will hang out into the goaf in a cantilever putting extra load on the supports.
chocks	Large hydraulic jacks used to support roof in longwall mining systems. Generally refers to four legged roof supports. Also known

	as powered supports, supports or shields. May be used to describe any roof support.
CMHSA	*Coal Mine Health and Safety Act 2002*
CMHSR	*Coal Mine Health and Safety Regulation 2006*
CMI	Coal Mines Insurance
CS	Coal Services
DAC	Direct access communication system. Provides a system of communication from the longwall to the surface control room. These are an intercom style system where the message is relayed to every point along the face and also the stage loading facilities. The use of amplifiers and loudspeakers allows the system to be heard over the noise of the longwall machinery. The intercom systems are not located at every longwall support but are installed at regular intervals along the face.
Department	NSW Department of Trade and Investment, Regional Infrastructure and Services (Trade & Investment). Formerly the Department of Industry and Investment (I&I NSW).
dog bone	A 'dog bone' is a connector between the line pans of the AFC.
double-chocking	If an area of roof is too exposed after the roof shields have advanced closer to the face they may be manually moved a second time, this is known as double-chocking.
Ex	Explosion protected. Equipment and plant is intrinsically safe.
flyrock	Rocks propelled from or off the cutting drums of the shearer while cutting.
flight bars	Part of the AFC, the flight bars are attached to the chain at right angles and are designed to catch the coal that falls onto the AFC and pull it toward the crusher at the maingate.
goaf	The space left following extraction of the coal seam where the roof material is allowed to collapse.
headway	Distance between the centre of the shearer and the last advanced roof support.
HPRI	High potential risk incident. Events or near-misses with the potential to result in a critical incident such as a fatality.
Intrinsically safe	A protection technique for safe operation of electronic equipment in explosive atmospheres and under irregular operating conditions. Clause 3 of the CMHSR defines ***intrinsically safe as follows:*** In relation to a circuit or electrical apparatus, means explosion-protected in such a way that any spark or thermal effect produced in the circuit or apparatus is incapable of causing ignition of an explosive mixture of methane or other flammable gases or vapours

	and air.
longwall (LW) mining	A system of mining that involves the extraction of large blocks of coal, with the coal being mined on retreat in slices up to one metre or more thick from the longwall face. Key longwall equipment: • shearer; • a steel chained armoured face conveyor (AFC); • self advancing, high capacity, hydraulic longwall supports (known as roof supports, chocks or shields); • a beam stage loader (BSL); • a crusher.
longwall panel	A large continuous block of coal, typically 100-400 metres wide and 1-3.5 kilometres long, suitable for longwall extraction
Maingate (MG)	Main access roadway connecting the longwall working face with the main roadways, usually an air intake roadway.
Methane (CH4)	Odourless colourless inflammable gaseous hydrocarbon. Methane is combustible when present in air in the range of approximately 5% to 15%.
Mimic Box	Control unit found on each roof support to control operation of the roof support.
Monorail	Steel Rail suspended from the roof that carries the longwall services, such as hydraulic hoses and the power supply.
pan line	A pan is part of the AFC and the stage loader through which the chain is guided, many pans are coupled together to make the pan line.
PPE	Personnel protective equipment. Safety equipment such as safety eyewear, helmets and footwear etc.
PTO	Planned task observation
RA	Risk assessment
remote	Radio controller for operating the shearer remotely. Also known as remote control, remote console, radio transmitter and radio control.
s.62	Section 62 of *Occupational Health and Safety Act 2000*
shearer operator	Operator controlling the shearer speed with corrections to the leading drum (roof) or the trailing drum (floor).

SLAM	Stop, look, assess, manage. A risk assessment tool.
Stage Loader	Equipment that receives the coal from the AFC and transfers it through a crusher on to the longwall conveyor belt for transport to the surface.
SWMS	Safe work method statement.
SWP	Safe work procedure.
tailgate (TG)	Roadway leading away from longwall face, usually a return air roadway.
TARP	Trigger Action Response Plans
TBT	Toolbox talk
top	A mine roof. Tops are part of the mine roof.
Two (2) leg support (roof support)	 The two legs of the support are connected into the canopy at an inclined angle and the supports are usually operated in Immediate Forward Support (IFS) mode. The main features of the 2 leg shield are: • The support density is not uniform throughout the working range • The lemniscate linkage ensures that the front of the top canopy maintains a constant distance from the coal, between the fully closed state and fully open position; • Full use of the reverse mounted ram; and • Side ram shields ensures good flushing protection.
XCN	Xstrata Coal (New South Wales) Pty Limited.
Xstrata	Xstrata Coal Pty Limited.