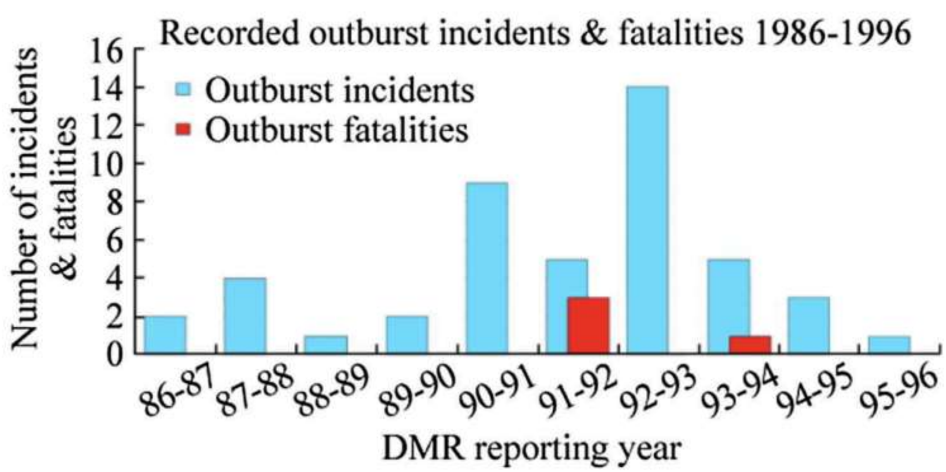
Outbursts in Mining Operations

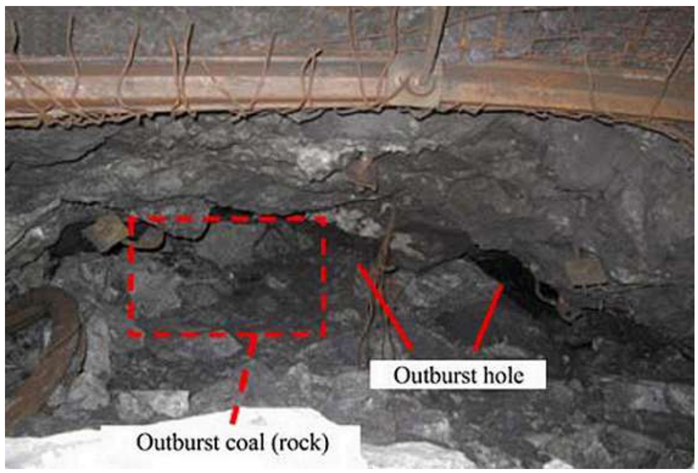
The term 'outbursts' is used to describe incidents where, in the process of coal mining, virtual explosions occur where both solid material and gas are suddenly and violently ejected from the coal face into the working area. The quantities involved are not small, and may include some hundreds of tonnes of solids, and thousands of cubic metres of gas (principally carbon dioxide and methane). Not surprisingly they pose a major threat to (and have taken) the lives of workers nearby. Over the period 1986 to 1996 there were some 43 outburst incidents in Australian coal mines, which took four lives. In total, twenty one men have lost their lives from outbursts in Australia up to 2017.[1]



From Black, IJMST, 2019

The issue of outbursts is of major interest in Illawarra mines, and in fact the first recorded outburst incident in Australia occurred in the Metropolitan mine at Helensburgh in 1895. They are not though unique to the Illawarra and have occurred elsewhere in Australia and overseas as is shown in the images from two mines in China.

Bailongshan Mine Outburst in September 2013 *From Qingyi Tu et al 2019*



Xinxing Mine outburst in November 2009 *From Qingyi Tu et al 2019*

The issues of outburst cause and prevention have received major attention, as discussed below (see, for example, https://ro.uow.edu.au/coal/187/)

Outbursts – with particular reference to the Illawarra

Outbursts of coal and gas have had a considerable impact on the history of coal mines operating under deeper ground cover than the earlier mines coal mines, opened on the escarpment in the Southern coalfield of NSW.

The coal seams in this area were laid down some 250 million years ago. Carbon dioxide and methane gases were produced in the process of coal formation (by anaerobic decomposition) and were entrapped in and around the coal seams. The volume of gas contained within a coal seam is described by the term "gas content" and is expressed in cubic metres (of gas) per tonne (of coal). The greater the gas content of the coal seam, the greater the possibility of an outburst occurring as the coal seam is mined.

Another term that commonly used in outburst prediction and prevention is "gas composition". The term gas composition has been used to describe the proportions of carbon dioxide and methane gases present in the coal seam. For example, the gas composition in an area may be 70% methane and 30% carbon dioxide. Note that the total of both gases is approximately 100%, as these two gases are the main gases created during the formation of coal. Both the gas content and gas composition can vary considerably in short distances within the coal seam.

Other factors leading to outburst proneness

The in-seam gases are "adsorbed" onto the surface of coal particles by a physical bonding phenomenon. The amount of gas retained by adsorption is governed by the stress in the coal caused by the surrounding strata and geological factors. If the stress is reduced by the mining process, the gas is "desorbed" (released) into the micro-spaces within the coal under pressure. The gas will then flow through the coal at a rate depending on the coal permeability, thus relieving the gas pressure. If the permeability of the coal is low, the gas pressure can remain high.

Added to the presence of the in-seam gas pressure, there are vertical stresses due to the mass of the strata overlying the coal seam, and horizontal stresses due to the inherent geology of the region. The situation is further complicated by the presence of geological anomalies such as faults and volcanic dykes thatintroduce weaknesses in the coal seam. The most common of these geological faults create little or no vertical displacement, but will have areas each side of the fault that slide against each other. These are known as slip or strike faults.

The combination of all these factors results in zones of the seam being under pressure and the coal seam may be weakened by a geological anomaly such as a fault. When the mining of the coal seam approaches these zones, a sudden and violent ejection of coal and gas may occur. These conditions usually arise a few metres ahead of the working face and/or the sides of the roadway. Where the coal adjacent to the underground roadway being mined is no longer of sufficient strength to resist the pent up stresses in the coal seam, the strata breaks and this releases gas from the coal.

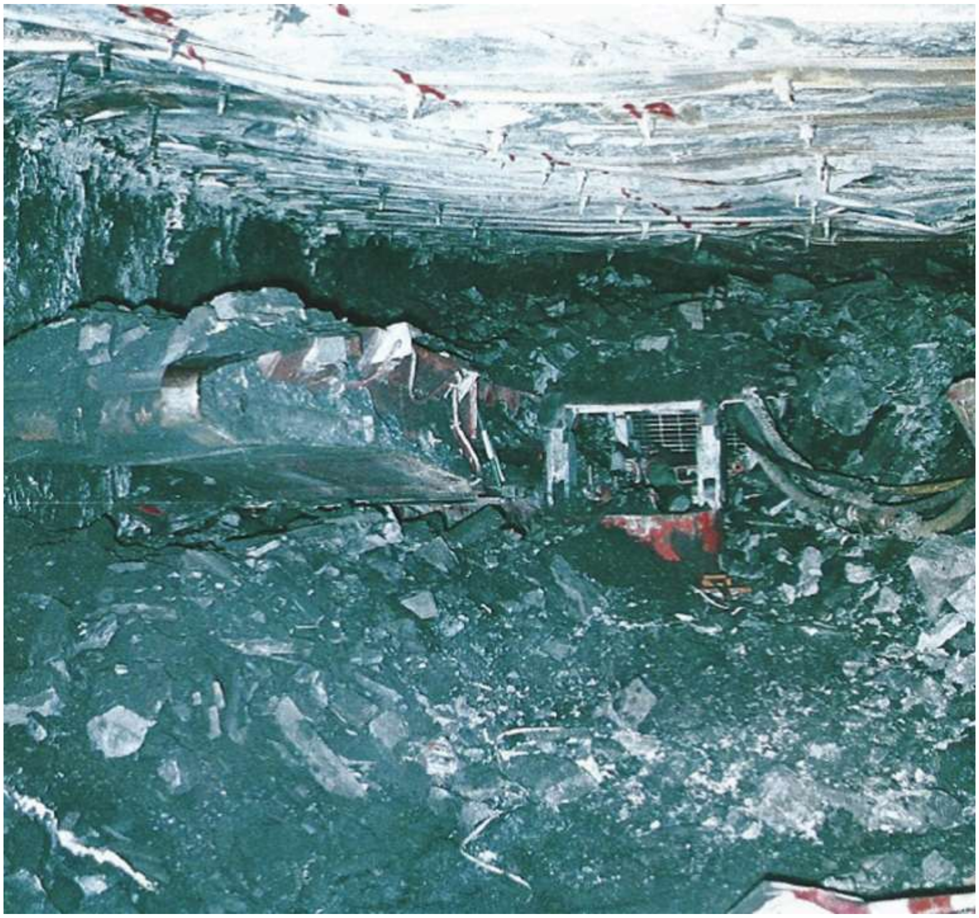
This is known as an outburst of coal and gas. Whilst both methane and carbon dioxide gases are released in outbursts, most of the fatal outbursts that have occurred in the Southern coalfield have been associated with carbon dioxide gas.

Outbursts in the Southern Coalfield

The first recorded outbursts occurred at Metropolitan Colliery in 1895 and 1896. They were both at a depth from the surface of 400 m, andin dyke structures exhibiting slip/strike features.

As there is no record of outbursts associated in mine workings at shallow seam depths, this confirms that the depth of the coal seam below the surface, is a significant factorin the potential for an outburst to occur.

Altogether there have been over 400 recorded outbursts at 10 collieries in the Southern coalfield, with 12 fatalities associated with these occurrences. The fatalities consisted of three separate outburst occurrences at Metropolitan Colliery (a triple fatality in 1896, a double fatality in 1926 and a double fatality in 1954), one fatality at Tahmoor Colliery (1985), a triple fatality at South Bulli Colliery (1991) and one fatality at West Cliff Colliery (1994).



Mining machine almost buried with coal from a fatal outburst at Tahmoor Colliery
Photo source: Tahmoor Colliery and Australian Geographic, volume 8, page 20

Trials and research

Research has focused on preventing outbursts by reducing the quantity and pressure of gas in the coal seam, ahead of the mining operations. The first trials commenced at Metropolitan Colliery in the 1960s under the direction of the late Dr Alan Hargraves. Amongst the many trials carried out was the drilling of large diameter (300 mm) in-seam boreholes ahead of the planned mining roadways, to release the gas contained in the seam prior to mining. This system proved to be only partially successful, however, it did lead to the development of a metering device, designed to measure the flowrate of methane and carbon dioxide gas flowing from the boreholes.[2] This information was used to set levels of acceptable flowrates for both of these gases, in determining strategies for further mining. Further, the information lead to the decision that the seam gas pressures encountered were insufficient to drain the gases, and the installation of a vacuum pump drainage system was not justified.

Other trials included shotfiring the face to induce a potential outburst, pulsed infusion of the face using water injected under high pressure, and mining the coal by shotfiring without the assistance of a kerf (horizontal cut in the coal seam) a practice known as “grunching” in the mining industry. Each of these methods were found to be largely ineffective.

Further research commenced in 1976 at West Cliff Colliery, a completely new Bulli Seam mine, where the depth of cover is approximately 500 m. In excess of 100 outbursts occurred at this colliery in its first year whilst roadways were being formed at the pit bottom. Soon after the initial outbursts occurred at the mine an investigation team, consisting of representatives of mine management and the Inspectorate travelled to the USA, United Kingdom and Japan to investigate current practices in seam gas drainage.

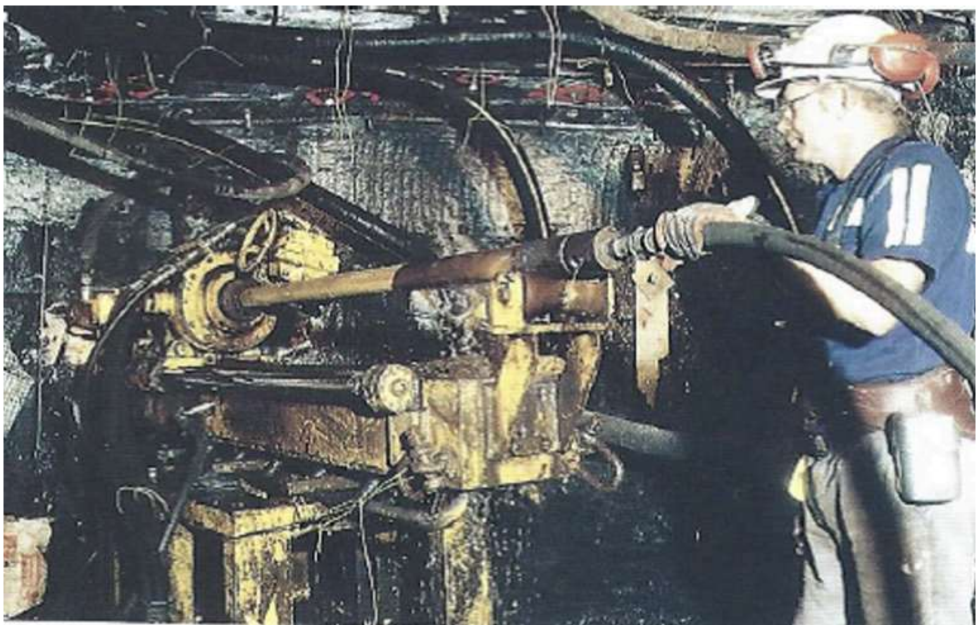
The late Dr Ripu Lama was the pioneer of the seam gas drainage research at West Cliff Colliery.

Subsequently, a mining technique called “drill and drain” was adopted. This technique consisted of drilling long in-seam boreholes ahead of the mine workings, and allowing sufficient time (often 90 days) for the in-seam gases to drain sufficiently from the coal seam. Gas drainage vacuum pumps were installed on the surface in 1980 and connected to a pipe network underground to remove the gas from the mine. The initial surface pump installation was later expanded to include an electricity generating plant, designed to operate with a methane/air mixture as a fuel. The “long hole” in-seam “drill and drain’’ programme, supported by the surface gas drainage plant vacuum pumps, proved to be highly successful.

Following the West Cliff example, circa 1980 Appin Colliery adopted the drill and drain technique after experiencing outbursting problems. Appin Colliery was an established colliery that had commenced mining the Bulli seam in 1962 at a depth of 550 m. Long-hole drilling ahead of the face was introduced, and the installation of vacuum pumps on the surface was completed in 1981.[3] A methane/air gas powered generating plant was installed in 1986, adjacent to the vacuum pump station.

Tahmoor Colliery commenced mining the Bulli Seam in 1979 at the depth from the surface of approximately 420 m. A major outburst, causing a fatality, occurred at Tahmoor Colliery in 1985. Subsequently Tahmoor Colliery adopted the "drill and drain" technique and installed a surface vacuum pump facility.

In 1992, the Tahmoor Colliery was the first colliery to introduce an Outburst Management Plan, which required that normal mining could not proceed until the gas content was below the "outburst threshold limit," based on research carried out by Dr Ray Williams of Geogas Pty Ltd.



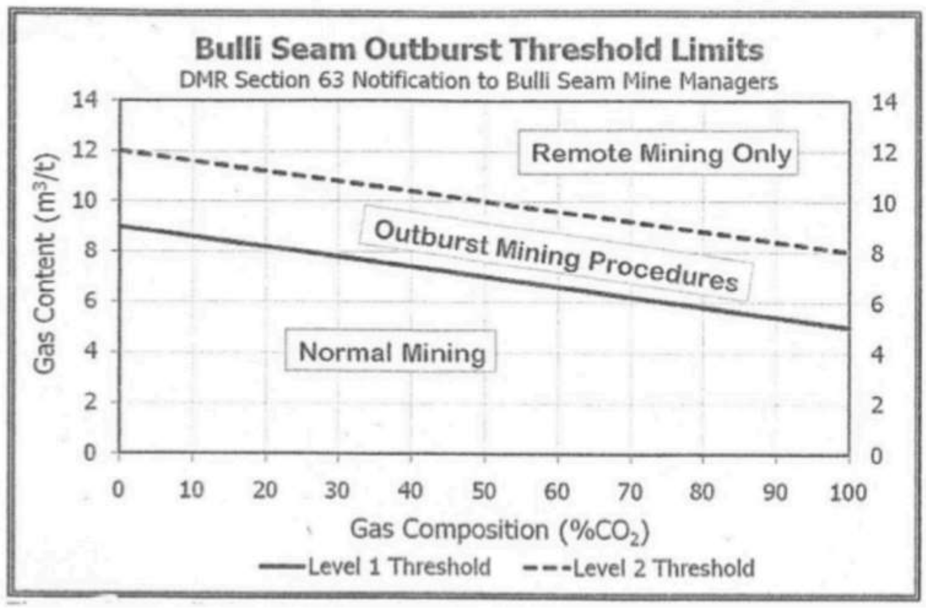
Drilling rig used to drill boreholes in the coal seam
Photo source: Tahmoor Colliery

An industry wide Outburst Committee was formed in the early 1980s to provide a technical focus and assist mine managements in understanding the outburst phenomenon. It was also realised that pillar stability research was relevant to outbursting. A researcher, Mr A. H. Wilson, had developed the hypothesis that there is a "yield zone" in the strata adjacent to an underground roadway in which the strata is relaxed.[4] He provided a formula to calculate the width of the yield zone, and for collieries mining the Bulli Seam in the Southern coalfield, that zone typically approximates 5 m.[5] This finding explained why outbursts often occurred when the underground roadway was mined to within 5 m of a geological structure such as a fault.

In 1991 an outburst, which killed three miners, occurred at the South Bulli Colliery.

The last fatal outburst in the Southern coalfield occurred at West Cliff Colliery in January 1994. Most of the areas mined at West Cliff had a seam gas composition which was mainly methane. However, when mining moved into an area with a seam gas composition that was high in carbon dioxide, a fatal outburst occurred.

In May 1994, the Chief Inspector of Coal Mines required all collieries to adopt an Outburst Management Plan. The diagram below provided a guideline for "outburst threshold limits" when mining in the Bulli Seam. The "outburst threshold limit" is set lower when the seam gas composition is higher in carbon dioxide gas.



Prescribed Bulli Seam Outburst Threshold Limits[6]

In 1994, Dr Ray Williams and John Weissman proposed modifying the concept of gas content below the "outburst threshold value" by introducing the Desorption Rate Index (DRI). The DRI is a measure of the rate at which gas desorbs, from a 200-gram sample of coal drillings after 30 seconds of crushing, and the residual gas is extrapolated. The DRI limit was proposed as 900 for both methane and carbon dioxide gases.

The only two outbursts on a longwall face in the Southern coalfield occurred on the same day in 1998 at the West Cliff Colliery, when the length of a longwall block was increased by 45 metres into an undrained area. Fortunately, whilst no injuries resulted from these two low intensity outbursts, the West Cliff Colliery amended its

Outburst Management Plan to ensure that all longwall blocks are adequately drained of in-seam gas before mining is permitted.

The Gas and Coal Outburst Committee that was formed for the 1995 Gas and Outbursts Symposium (Wollongong) and the NSW Government Department – Mine Safety Operations unit, identified the need to hold regular Seminars to maintain a focus on the issues associated with gas and coal outbursts and mine gas management. Consequently, half day seminars are held twice per year in Wollongong on these topics.

The table below provides a summary of all reported outburst occurrences in the Southern coalfield of NSW.

Colliery	No. of Outbursts	Size in tonnes	Gas	Geological Structure
Appin	26	2 - 88	mainly CH_4, with CO_2 on dykes.	Predominantly strike slip faults; mylonite zones.
Brimstone (closed)	2	30	CO_2	Mainly dyke related structures with strike slip movement.
Corrimal (closed)	4	12	CH_4 & CO_2	Shear zone associated with minor faulting & dykes.
Kemira (closed)	2	60 - 100	CO_2	normal fault with mylonite.
Metropolitan	154	Up to 250	mainly CO_2 with minor amounts of CH_4	Predominantly with dykes & faults that exhibit slicken sides & mylonite.
Bellambi West (South Bulli)	13	1 - 300	mainly CO_2	Strike slip faults with mylonite; dyke zones & thrust faults.
Tahmoor	90	5 - 400	mainly CO_2	Mainly strike slip faults; with dykes (110° - 135°) & thrust faults: mylonite usually present.
Tower	19	1 - 80	mainly CH_4	Mainly strike slip faults with dykes.
West Cliff	254	4 - 320	mainly CH_4 with CO_2 to the NE development	Predominantly strike slip faults (100° - 110°) with slicken sides & mylonite; dykes and thrust faults have been associated with outbursts.

Outburst occurrences in the Bulli Seam of the Southern Coalfield as at 2002[7]

Over 250 outburst incidents were recorded at West Cliff Colliery, which is more than any other colliery in the southern coalfield.

The largest outburst in the southern coalfield occurred at Tahmoor Colliery in June 1985.That outburst released approximately 400 tonnes of broken coal and instantaneously released an estimated 4,500 cubic metres of irrespirable carbon dioxide gas.

[1] Black D, I J Min Sci Technol 29, 2019, 805-824

[2] A. J. Hargraves "Planning and Operation of Gaseous Mines", The Canadian Mining and Metallurgical Bulletin March, 1973, diagram of emission meter, p. 4.

[3] P. Eade "Case Study Outburst & Gas Management", Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2002, pp. 105-113.

[4] A. H. Wilson, "Research into the Determination of Pillar Sizes", The Mining Engineer, June 1972.

[5] Width of the yield zone (m) = 0.005 x seam height (m) x depth of the seam from the surface (m). An example calculation: width of the yield zone = 0.005 x 2.5 m seam height x 400 m depth = 5 m.

[6] Source: Legal directive (Section 63 notice) issued by the NSW Inspectors of Collieries on behalf of the Chief Inspector of Coal Mines.

[7] C. Harvey "History of Outbursts in Australia and Current Management Controls", Coal Operators' Conference, University of Wollongong & the Australasian Institute of Mining and Metallurgy, 2002, pp. 36-46.

About Us Contact Us Timeline Map