DEFINITION OF OUTBURST THRESHOLD LIMITS FROM CORE TESTING

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ABSTRACT

This paper is primarily concerned with assessment and interpretation of the rate of gas desorption during crushing of coal cores. The rate of gas desorption is a key parameter in determining outburst proneness.

In defining gas content threshold limits for outburst assessment, it is suggested that gas content thresholds be tied to a standard gas desorption rate. The gas desorption rate as routinely measured by GeoGAS's fast desorption method of gas content determination, provides a simple and readily quantifiable approach to the setting of gas content thresholds. These rates should be quantified for other methods of fast desorption gas content testing.

The approach for the setting of gas content threshold values rests with acceptance of the fundamental role desorption rate plays in outbursting, and of the ability of techniques such as the GeoGAS DRI to accurately and consistently measure it.

The desorption rate of coal from outburst prone, South Coast mines is used as the bench mark and is compared with other coals in New South Wales and Queensland.

The effects of permeability and gas reservoir size are also discussed.

A Desorption Rate Index (DRI) of 900 is suggested as a threshold for outburst proneness. For operating mines, this should be viewed in the context of an outburst management plan, where of equal concern, is knowing with certainty, that mining is taking place in coal with a DRI below the threshold.

INTRODUCTION

There is an immediate need to provide hard data to enable collieries to develop timely and suitable gas and outburst management plans, and for deposits being evaluated, to more adequately assess outburst proneness as part of the feasibility studies. There is a particular need in Queensland, where mines working from shallow, non outburst prone environments are proceeding to deeper, potentially outbursting areas. Mine planners need to know well in advance, where different aspects of gas and outburst management plans come into force.

The problem is one of defining threshold limits for safe mining that are based on mine specific criteria, rather than verbatim transferal of approaches and thresholds used elsewhere.

Gas desorption rate has long been regarded as significant to outbursting. Numerous indices have been developed locally and overseas that tie outburst proneness to the quantity of gas desorbed (or pressure build up in a confined chamber) from a specified size fraction over a specified time (an extensive listing in given in Lama and Bodziony, 1996 - Table 9.1 page 307).

Many of these laboratory developed indices have been used in mine operations. The most notable local method is the Hargraves EV meter, which measures the rate of gas desorption from a small (4g) dry coal sample. The method was used at Metropolitan Colliery, Collinsville and Leichhardt Colliery. The “EV method” was useful in characterising areas of coal, but suffered (along with other similar methods - eg ΔP_{0-60} , the Polish Desorbometer, V, V_0) by utilising a small sample (3-10 g), and requiring dry coal.

Gas content is a static measure of gassiness, but in so far as desorption rate increases with increasing gas content, it is also a measure of desorption rate. The higher desorption rate for CO_2 over CH_4 is taken into account by setting different gas content thresholds eg CO_2 and CH_4 have similar desorption rates at gas contents of 6 m^3/t and 9.5 m^3/t respectively (Bulli seam Appin, West Cliff, Metropolitan Collieries).

The gas content thresholds (as part of an outburst management plan) have been demonstrated to work at these mines as evidenced by outbursts now being a rare event.

Does a gas content threshold of 9.5 m^3/t for the Bulli seam equally apply to other seams, eg the Goonyella Middle seam, the German Creek seam, the Wynn seam. These coals have different characteristics to the Bulli seam.

In the authors view, there should be a return to using a method that directly measures the gas desorption rate, but overcomes the problems of sample size and moisture of the indices mentioned earlier. The method that is central to this paper aims at addressing this need, and should be readily acceptable at least in practical terms, as it is a simple addition, to an established and accepted methodology.

Unless otherwise stated, gas content values refer to total desorbable gas content (Q1+Q2+Q3) calculated to 20°C and 101.3 kPa absolute.

INSTANTANEOUS OUTBURSTS OF COAL AND GAS - A MECHANISM

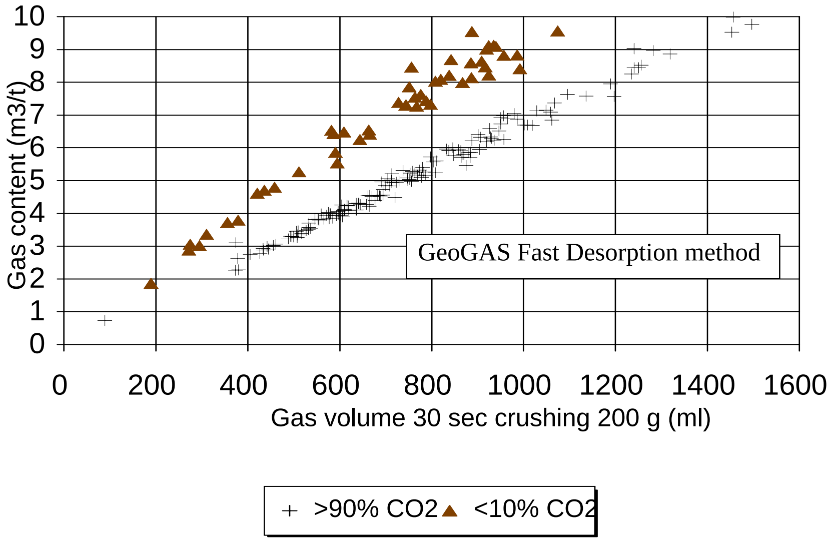
While a wide array of factors can be listed as contributors to outbursting, in Australia, these can arguably be reduced to two basic parameters:

- **Rapid gas desorption rate** (dependent on particle size, gas content, gas composition, gas pressure)

- **Low permeability** (dependent on insitu stress conditions, coal strength/modulus, gas pressure gradient, fluid saturation, cleat development and mineralisation)

The consequences of an outburst are additionally determined by the size of the gas reservoir (seam thickness, extent of mylonisation).

Fig.1 Gas Content and Desorption Rate During Crushing



The effect of both gas composition and gas desorption rate is readily seen in figure 1, contrasting dominant CH_4 areas and dominant CO_2 areas from the Bulli seam at West Cliff Colliery (Williams and Weissman, 1995).

The author believes the most important parameter is gas desorption rate, in conjunction with the gas content gradient ahead of the face. The process is described with the aid of figure 2, which shows what should be a generally accepted sequence of events leading up to the point of outburst initiation.

Normal mining conditions are characterised by a relatively low gas content gradient ahead of the face (figure 2a). The steepness of the gradient will increase according to the permeability and the speed of face advance. The distance from the face to the virgin gas content region would be in the vicinity of 5 m to 20 m for an actively advancing face. While mining is proceeding, gas is continuously being bled from the coal in the face area.

In outburst prone conditions, the coal hardens in response to increased stresses, and the permeability declines as the stress increases. High stressed, low permeability zones are often associated with the load concentration that occurs as the coal "barrier" between the face and the outburst structure is progressively diminished (figure 2b). A characteristic of this tightening is a reduction in gas emission, and the coal being harder than normal to cut. Such an effect has been associated with outburst occurrences in Australia. The gas content gradient is steep, with near virgin gas contents occurring within metres (or less) of the face.

With continued mining, this highly stressed "pillar" reaches the point of rapid or sudden failure (figure 2c). At this time, the stress on the coal is suddenly reduced and the ambient fluid pressure on the coal changes from being mostly above the gas desorption pressure to suddenly being well below the desorption pressure for the gas content of the coal.

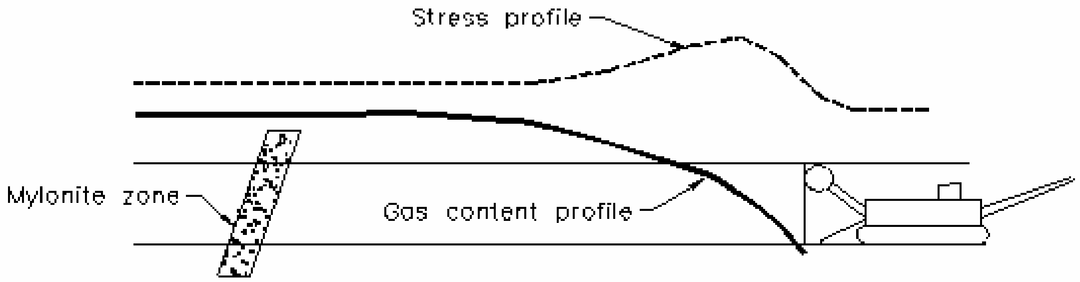


Fig.2a Normal Stress Distribution and Gas Content Gradient

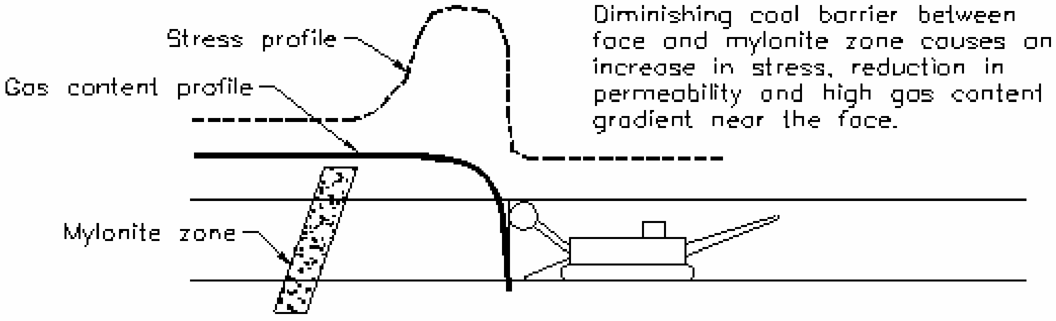


Fig.2b Peak Stress Concentration and Gas Content Gradient

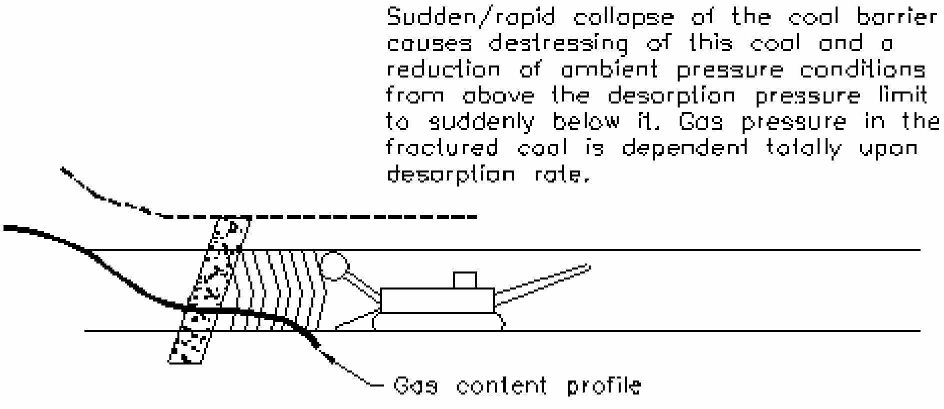
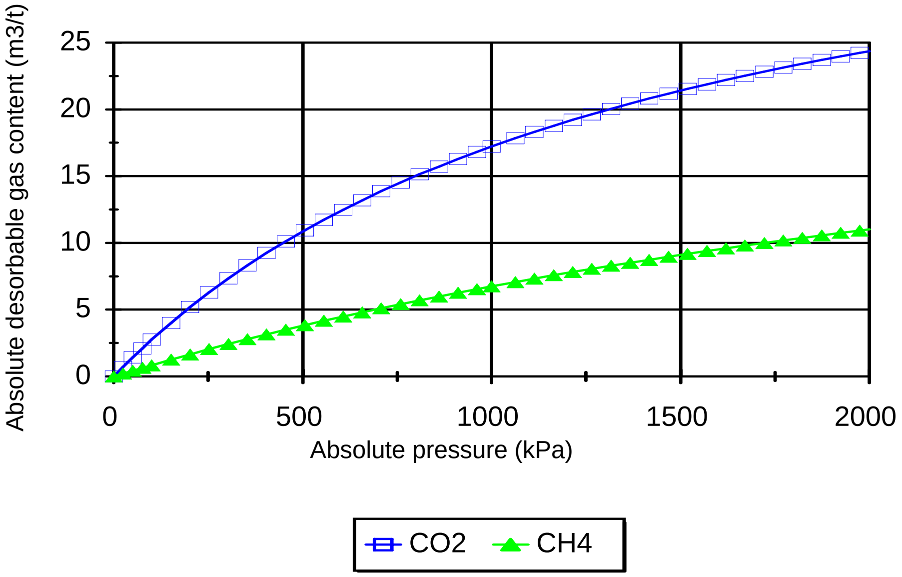


Fig.2c Conditions at the Time of Outburst Initiation

It is useful to make the distinction between the process of slow gas emission during gas drainage and the sudden gas emission during an outburst. In the former there is time for a near state of equilibrium to be achieved between gas pressure and gas content (eg according to the sorption isotherms in figure 3). In the latter, the pressure is reduced so quickly, that no such equilibrium can be achieved. *(For all but pulverised coal, there is a considerable time delay between when the gas pressure is reduced and when the gas content decreases to be in equilibrium with that gas pressure).* None-the-less, gas pressure is generated (not necessarily very high) in the newly created fractures according to the rate at which the gas can desorb. Because for similar gas contents, CH_4 desorbs its gas more slowly than CO_2, it is CO_2 that is more prone to outbursting.

Fig.3 Example Gas Sorption Isotherms



The adsorbed gas content of the coal is in itself inconsequential. It is only when the gas desorbs from the coal matrix that it comes into play. The important factor is how quickly this is achieved**.** The desorbing gas exerts a pressure that promotes outward projection of the coal. With small particle sizes, the desorption rate can be increased to the point where the coal becomes entrained in the desorbing gas.

Central to the argument is the notion that:

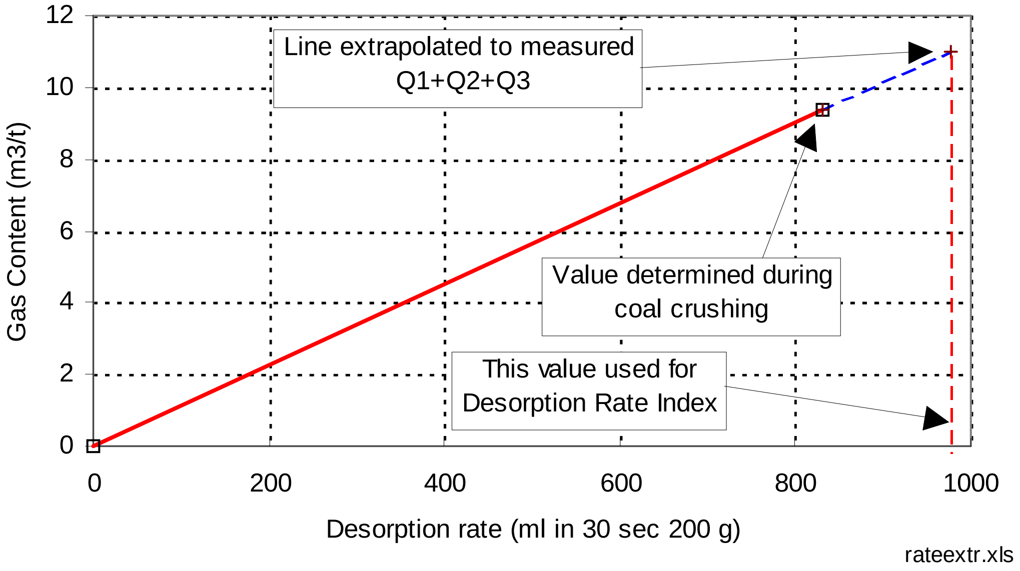
- The gas pressure in the fracture network is a combination of how fast the gas desorbs and how fast the gas can escape along the fractures - ie the permeability of the fracture network.
- Until the gas desorbs, there is no gas pressure generated in the fracture network.

GeoGAS DESORPTION RATE INDEX

The GeoGAS Desorption Rate Index (DRI) is the quantity of gas desorbed after 30 seconds of crushing a 200 g sample. For the fast desorption method, between 80% and 90% of the Total Desorbable Gas Content is liberated during crushing (the remainder of the gas is desorbed prior to crushing).

The relationship between the DRI and gas content has proven to be linear (eg figure 1). The desorption rate during crushing is related to the gas content of the coal being crushed. The DRI for the test is determined by recalculating it to the Total Desorbable Gas Content of the full sample (figure 4). This includes Q1 and Q2f - the proportion of gas desorbed prior to crushing.

Fig.4 Extrapolation of the Desorption Rate Line to the Q1+Q2+Q3 Value

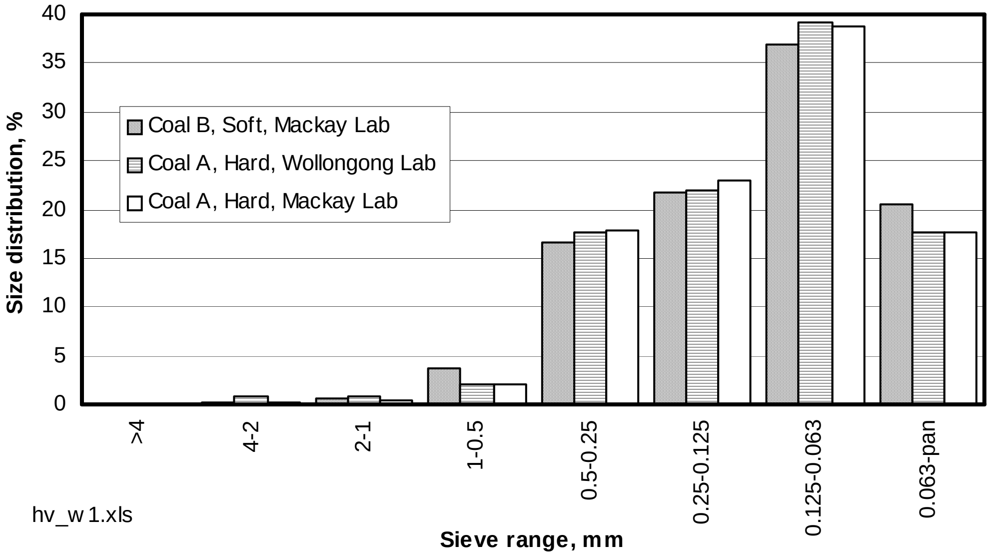


It is important that the crushing apparatus deliver the same amount of energy in the same period of time. GeoGAS’s ring mill crushers have motor speed controllers that are set to deliver consistent crushing between the Wollongong, Muswellbrook and Mackay laboratories. Periodic sizing checks are made between laboratories, of the material crushed after 30 seconds (figure 5, graph series 2 and 3). On the basis of comparing the DRI/gas content relationship from recent and old samples from the same colliery, our oldest crusher has not shown any degradation over the past five years.

Changes in coal hardness should result in differences in desorption rate. Sizing comparison of a soft Queensland coal with a hard coal show what appear to be small differences in sizing (figure 5 - compare graph series 1 to series 2 and 3). Whether these differences are significant, is the subject of continuing research. It could be argued that if the DRI is significantly sensitive to coal hardness, that this also constitutes a valid outburst proneness parameter.

Note: The full crushing period is 7 minutes after which time > 80% of the material is -0.063 mm in size.

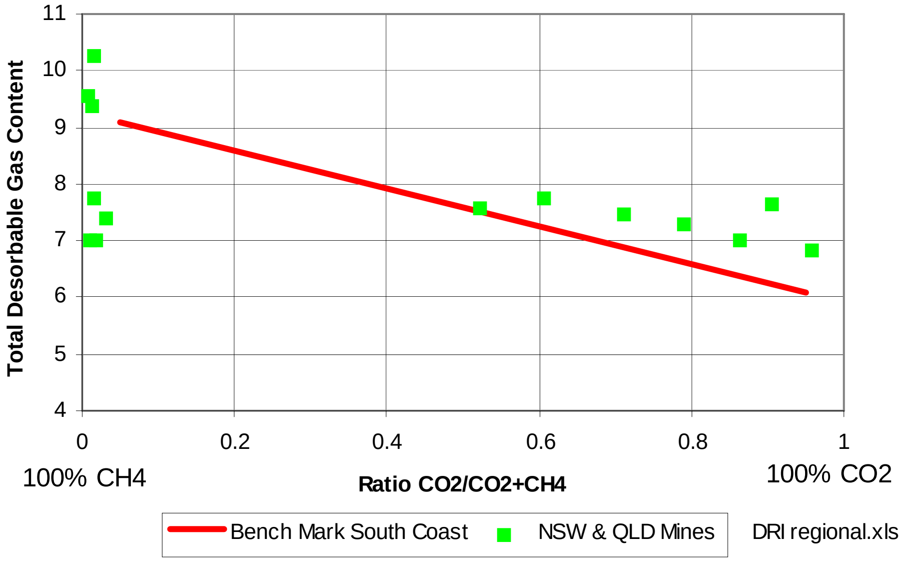
Fig. 5 Comparison of Particle Size Distribution After 30 Seconds Crushing



COMPARISON OF GAS CONTENTS FOR A CONSTANT DESORPTION RATE

The “bench mark” coals of West Cliff, Appin and Metropolitan Collieries plot close to the threshold line in figure 6. The isolated points show the inherent differences in gas content to produce the same desorption rate for various mines in New South Wales and Queensland. The 900 DRI is regarded as being the threshold for outburst proneness. It can be seen that some dominant CO_2 coals (Picton/Burragorang Valley area South Coast mines and Hunter Valley) have relatively high gas contents at 900 DRI, ie are less outburst prone.

Fig.6 Comparison of Gas Content Values for a Desorption Rate Index of 900



Some of the dominant CH_4 coals have similar gas contents (areas of the Bowen Basin), one has a higher gas content (Hunter Valley/Newcastle), and some have much lower gas contents (areas of the Bowen Basin, and South Coast).

GAS CONTENT THRESHOLD VALUES

The South Coast threshold values have been initially determined on largely empirical grounds from starting points of 9 m^3/t being the CH_4 threshold limit in (West) German mines, to 5 m^3/t (Q1+Q2) being an empirically defined limit for CO_2 at Collinsville. There have been subsequent modifications based on arguments such as those presented in this paper.

The limits of 9.5 m^3/t for CH_4 and 6 m^3/t for CO_2 (with some variations between mines) have to date proved to be reasonable, with no surprises occurring, to the authors knowledge, in coal that has been predrained to the required level.

On the basis that gas desorption rate is the critical differentiating parameter, the relative gas content thresholds for 100% CO_2 and 100% CH_4 do reflect the similar gas desorption rates at these values. Linear regressions of the data contained in figure 1, show that a 100% CH_4 coal of 9.5 m3/t corresponds in desorption rate to a 100% CO_2 coal at 6.2 m3/t. These relativities in desorption rate are roughly similar for both intact bore core (initial desorption for Q1) and coal during crushing (GeoGAS DRI). The latter provides a much clearer distinction and is used in figure 1.

The 900 DRI proposed here, aims at creating a work environment of zero gas dynamic incidents (GDI’s). In other words, if the gas content is reduced to this value, uncontrolled rapid releases of gas should not occur, regardless of the structural state of the coal. Arguments over whether a rapid gas release incident is an outburst or not, are irrelevant. Any such incidents should not be part of day to day mining.

In setting limits, careful consideration needs to be given to the mining history in respect of any occurrence of GDI’s and the corresponding DRI. The opportunity should be taken to investigate any such occurrence, however small.

PERMEABILITY

In assessing the outburst proneness for different areas, consideration also needs to be given to the likely range of in-situ coal permeability. While this is a more difficult parameter to quantify, it is suggested that significance be attached to only large differences in permeability. For example, on the South Coast, the permeability ranges from say 0.01 to 5 mD. It is pointless trying to differentiate a mine yielding a permeability measurement of 4 mD compared to one with a measurement of 0.5 mD. Permeability can change over this range very quickly, especially in response to stress concentrations associated with outbursting.

On the other hand, it is probably being unnecessarily too cautious to assign a 900 DRI threshold limit to a colliery whose permeability regime is no where near that of the South Coast. For example, for the relatively shallow underground mines in the Hunter Valley and Bowen Basin, let us assume that they exhibit high gas desorption rates. At depths from 100 m to 200 m, permeabilities may range from say 20 mD to 100 mD. In this range, high gas content gradients are unlikely to develop even when mining up to geological structures that would otherwise be outburst prone.

There are four possible categories as follows:

1. Low permeability/high gas desorption rate - Outburst prone, (South Coast, various areas of the Bowen Basin >200 m depth)

2. High permeability/high gas desorption rate - Non outburst prone

3. Low permeability/low gas desorption rate - Non outburst prone

4. High permeability/low gas desorption rate - Non outburst prone

Points 3 and 4 are of no consequence from an outburst view point. The main requirement is to identify the transition from 2 (high permeability) to 1 (low permeability) for high gas desorption rates. This gradation is most likely to occur in the Bowen Basin, where with increasing depth, permeability decreases and gas desorption rate increases.

There is little practical value in arguing over whether the permeability is low enough to cause outbursts. If the gas desorption rate is around the suggested outburst threshold level, high permeability coal will almost certainly cause gas emission problems. Here the solution for both high and low permeability coal is basically the same - gas predrainage (or gas capture with high permeability). The differences are more reflected in gas management plans and drilling design.

It is suggested that the quickest way of assessing these broad permeability trends is curve matching of the borehole flow, rib emission, gas content profile/gas pressure profile data using a gas reservoir simulator such as SIMED II.

GAS RESERVOIR SIZE

The discussion so far has centred upon initiation of an outburst. Consideration also needs to be given to the consequences of an outburst. Gas desorption rate is again important, but the extent to which the rate is sustained will be influenced by the size of the gas reservoir - primarily the thickness of the coal seam. With thicker seams, the quantity of mylonite would normally be greater, producing larger outbursts - all other parameters being equal. The increase in seam thickness caused by thrust faulting is an additional important consideration.

Assessment of gas reservoir size is straight forward in seams of consistent quality, but is considerably more difficult in thick, highly banded seams such as the Wongawilli seam. An approach for such an evaluation is given in Williams and Maddocks (1993).

CONCLUSIONS

This approach for the setting of gas content threshold values rests with acceptance of the fundamental role desorption rate plays in outbursting, and of the ability of techniques such as the GeoGAS DRI to accurately and consistently measure it.

GeoGAS is currently using this approach to define outburst threshold levels (in the context of a management plan), and continuing to research the method. The prime research focus is on assessing the significance of variations in particle size during crushing, for comparison between laboratories, over time, and between coals of contrasting hardness.

For surface borehole exploration in largely green field areas, the 900 DRI (or equivalent) can be used as an indicator of when outbursting should be considered as part of mine feasibility studies.

For operating mines, the 900 DRI threshold needs to be tied to an outburst management plan in which the totality of the risk involved has been formally considered. Of equal concern from an operating point of view, is to know with certainty, that the mining environment is below the threshold. New techniques such a real time return gas monitoring (Williams and Slater, 1997) should prove to be an important aid in validating the state of gassiness of the coal being mined.

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