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THE ROLE OF DIRECTIONAL DRILLING FOR SAFETY IN COALMINING

YÖNLENDİRİLMİŞ SONDAJIN KÖMÜR MADENCİLIĞINDE GÜVENLİK AÇISINDAN ROLÜ

Thomson, Scott, Advanced Mining Technologies Pty Limited, 18 Lucca Road Wyong, Australia.

ABSTRACT

Risks associated with gas and water in-rushes can be mitigated by the application of drilling techniques. This paper addresses some of the sources of risk in Australian coal mining and reports on the current status of the application of drilling to alleviate those risks. Drilling principally helps in addressing the potential for outburst events and face gas-outs by enabling gas to drain from the borehole thereby lowering bulk seam gas content.

OZET

Ani su ve gaz degajı ile ilgili riskleı sondaj yöntemleıı uygulamasıyla azaltılabilir. Bu bildiri, Avusturalya kömür madenciliğinde görülen bazı risk kaynaklarını veımekte ve bu risklerin en aza indirilmesi için uygulanan sondaj yöntemlerinde kat edilen son gelişmeleri açıklamaktadır. Sondaj uygulamaları, potansiyel gaz patlaması olabilecek yeıleıin tesbitinde ve kömür damarı içerisindeki gazın drene edilmesine olanak tanıdığı için, kömür daman gaz içeriğinin azaltılmasında yardımcı ulamaktadır.

1. INTRODUCTION

Global demand for coal as a cheap, reliable energy source has resulted in increased production levels in many underground mines which are affected by high inherent gas levels. High levels of gas content provide a significant safety risk to personnel engaged in the mining process. In-seam drilling designed to lower the gas content to below threshold levels is in many cases now necessary in order for mining to proceed.

Mine safety is clearly the responsibility of management and recent developments in Australia confirm the legal requirements for duty of care by mine officials. Test cases involving gas and water in-rushes emphasise the important role that drilling can play in mitigating risk in coal mining. Legal requirements vary internationally but responsible mining in increasingly hazardous conditions will inevitably demand faster, cheaper, and more accurate in-seam drilling. Improvements to drilling technology and associated diagnostic geophysics is actively being pursued to address a perceived need for improved mine planning and pre-drainage of potentially high levels of in-seam gas.

Safety is an important issue in mining for more than the humanitarian aspect. There is a strong link between highly productive mines and those with excellent safety records (Parkin, 1997). In gassy mines efficient drilling practice and drainage of gas can ensure that mine productivity matches that of mines operating in less hazardous conditions.

2. DRILLING TECHNOLOGIES USED IN AUSTRALIAN UNDERGROUND COAL MINING

The environment in which drilling is undertaken in coal mines imposes severe restrictions on the type of drilling equipment being used. The main concern is the presence of coal dust and methane in confined spaces and the potential for an explosion. As a consequence all components have to be Australian Mines Department approved for safe operations including a flameproof electric motor and starter (control box), no exposed aluminium components, methane monitor and automatic shut-off, fire resistant anti-static components, fire resistant hydraulic oil and an approved survey instrument.

The necessary modifications result in a safe drill rig which is heavier and more expensive than an equivalent rig utilised in surface or hard rock operations. A suitable underground gas drainage and exploration rig would have the following specifications:-

- (i) 75 kW, 1000V hydraulic power unit to power the rig and the water pump,
- (ii) 2501/min @ 10 MPa high pressure pump,
- (iii) 135 kN thrust and pull,
- (iv) 1500 to 2000 Nm torque, NQ capacity rotation unit,
- (v) track mounted,
- (vi) compact enough to operate in a roadway and allow vehicles to pass.

Although rotary open-hole drilling has traditionally been predominant, down-hole-motor drilling has become the major form of in-seam drilling in recent years. In-seam exploration drilling has also become more common with a need to better identify and define structures which would adversely affect the high levels of longwall production. This has created a need for longer directionally controlled boreholes with the increased use of down-hole-motors. Longer boreholes have meant higher strength rods, improved surveying techniques and higher capacity rigs (Hungerford, 1995).

Borehole depths with down-hole motor drilling has also been restricted by increased surging as the depth increased. For long-hole exploration, the bit diameter has been increased from 89 to 96mm with an increase in the size of the bend of the downhole motor from 1 to 1.25 degree to maintain the ability to climb. With the increased clearance, reduced surging and the use of more powerful downhole motors, borehole depths in excess of 1500m are possible.

An example of a recently drilled directional hole is presented in Figure 1. The hole was drilled for gas drainage purposes to a depth of 701m. Seam profile is consistent and roof intersections are relatively widely spaced (> 100m). More frequent roof "touches" are required for detailed exploration purposes.

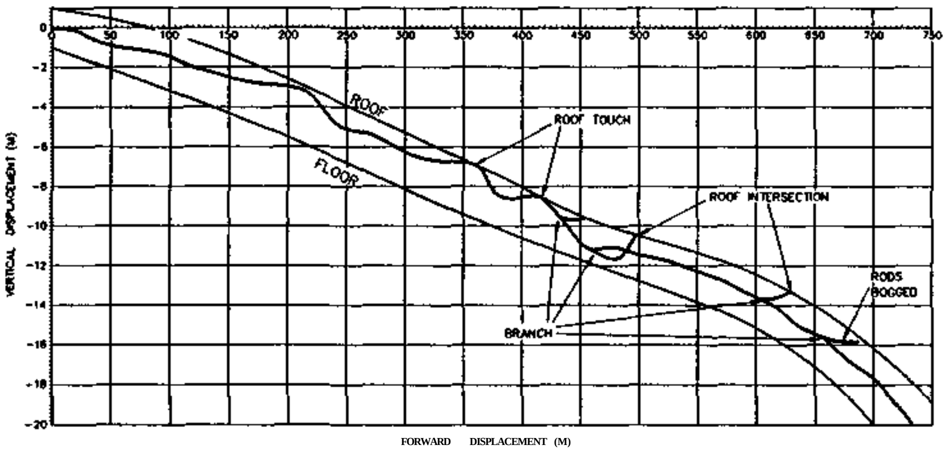

Figure 1 - Profile of a directional drilled hole for gas drainage purposes.

3. DEFINING THE HAZARDS

The major safety issue that can be addressed through drilling is the control of seam gas. Seam gas is predominantly comprised of potentially explosive methane (CH_4) and carbon dioxide (CO_2). Drilling itself may be hazardous if provision is not made to control gas surges from the borehole. Activities where hazards are likely to occur include:-

a) During drilling - risk addressed by establishing safety protocol for the drilling operation.
b) During development - drilling used in mitigating against potential outburst hazards.
c) During longwall extraction - drilling used to avoid high gas levels at the working face.

For water in-rush similar safety protocols need to be set up during drilling and the major hazard is in unexpected intersection of flooded workings during mine development.

3.1 Gas/water hazards whilst drilling

In drilling in gassy areas or where a water influx is a real risk there are a number of precautions that must be taken to ensure the safety of operators. These risks should be addressed by

Occupational Health and Safety (OH&S) policies adopted by the mine or drilling contractor. The main areas of concern are:

- material forcibly ejected from the hole injuring drill operators.
- gas escaping from the hole and creating a potentially explosive mix.

In drill rig setup it is important to anchor the rig securely either by bolting to the floor or by jacking the rig against the roof and floor. The next important step is to install a standpipe in the hole securely grouted against the side wall of the hole and rib. Standpipes are usually 6m X 100mm. Grout is then applied between the standpipe and the wall of the hole and plastered around the collar. The objective is to ensure that all cuttings, gas, and water coming out of the hole during drilling is controlled through the standpipe and does not enter the mine atmosphere. Key issues include ensuring that grout is of adequate strength, of sufficient quality (fast setting, non shrink preferred) and has completed the seal around the standpipe.

A stuffing box is located at the end of the standpipe and its purpose is to prevent the escape of gas from the hole to the working area. The drill rods run through the stuffing box and a seal is maintained around them by glands and a gasket. A perfect seal is not critical and it should be acknowledged that wear will be experienced through the running of rods through the glands.

It is important to note that any gas escaping from the seal will be extremely pure (likely >90% methane). It will therefore pass through the explosive range on dilution into the mine atmosphere. Adequate ventilation (> 4m /s) should occur at the drill site to ensure fast dissipation. Gas monitors should be installed at the rig site and statutory limits adhered to, namely 1.25% methane - power is shutdown, 2.0% methane - drillers are withdrawn.

The gas/water separator is positioned on the return side of the working area. All valves and fittings used should be rated above seam gas pressure. The drill operator now controls the flow of material from the borehole and provided the standpipe and grouting is secure, the gasket seal is maintained, and the valves are rated accordingly, drillers are at no risk of being injured from material ejected from the hole. In addition, provided ventilation is adequate, insufficient gas can escape to create a potentially hazardous working environment.

3.2 Drilling to mitigate outbursts during development

In Australian gassy coal mines pre-development drainage of gas is often necessary to meet governmental regulations regarding gas content thresholds. Drilling is carried out to lower overall gas contents and minimise the risk of an outburst event occurring during development mining. The common association of outbursts with geological structures provides a dual role for drilling: find structures and lower the overall gas content. In Australia drilling is the pre-eminent method of alleviating the outburst risk.

Outbursts may occur in coal with a gas content exceeding 7-9m^3/t. Propensity to outburst depends upon a number of factors in addition to total gas content including gas type (more violent outbursts have been associated with high CO_2 contents), coal seam permeability, rate of development drivage, length of gas drainage time and the presence of geological structures and mylonite.

Large diameter (300mm) short hole (20-40m) drilling was carried out in the 1970's to relieve potential outbursting (Gray, 1995) with some success. In the 1980's rotary drilling to 750m was achieved allowing longer gas drainage times and potentially safer conditions. However, the holes were long but inaccurate, in some cases deviating more than 45 degrees from their planned path.

Nevertheless, until recently rotary drilling cross-panel was commonplace in the gassy mines of the Southern District, usually to lengths of 250-320m. Outburst events continued to occur however, suggesting that rotary drilling was providing uneven drainage of yet to be mined coal. Worse, drainage and deviation problems tended to be greatest in areas of geological complexity, precisely the areas likely to be outburst prone. It should be emphasised that the problem does not lie with rotary drilling per se, but in the regularity and control associated with survey points.

The unreliability of rotary drilling is exemplified by the results of a recent drilling project at a Queensland longwall mine with up to 70m lateral offset on a projected 240m hole (Fig.2|

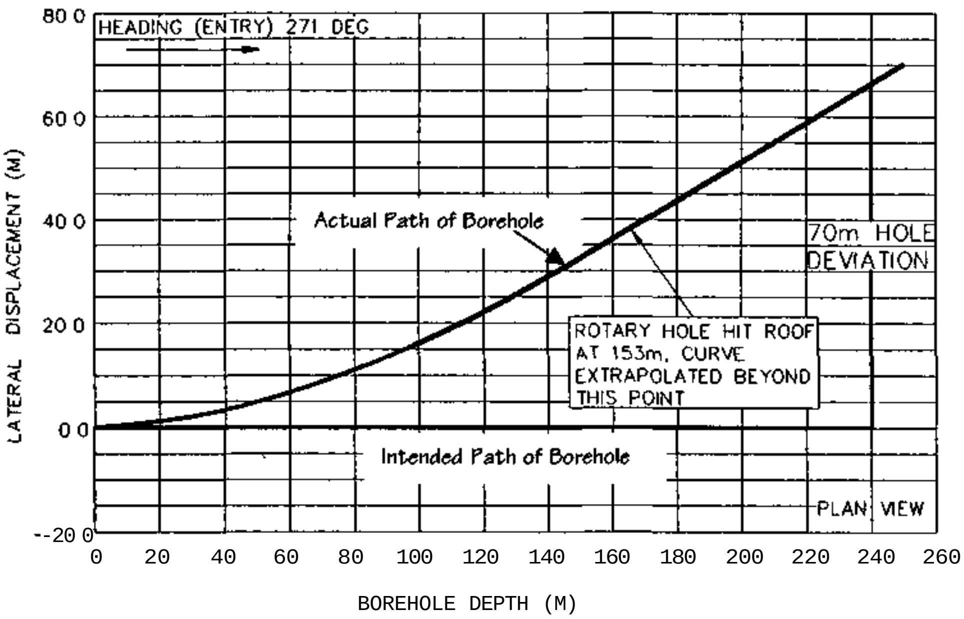

Figure 2 - Sample rotary hole from Queensland longwall operation showing deviation from planned path.

The additional problem of rotary drilling, namely controlling the vertical deviation, is reflected in the termination of the hole at 153m after intersecting the roof. To continue drilling in coal, the operator is forced to either re-start the hole from its source or continue drilling in the roof, hoping that gravity will prevail and bring the bit back into the seam. The latter course of action is likely to be time consuming with a very uncertain outcome.

The introduction of directional drilling using downhole motors has increased since the mid 1980's and is now the major type of in-seam drilling carried out in Australian conditions. Very long (1500m+) and extremely accurate (+/- 0.5 degrees or less than lm every 100m) holes have been drilled using downhole motors.

Central to this improved length and accuracy performance has been the introduction of (almost) real time survey tools, in particular the DDM MECCA (Directional Drill Monitor using

Modular Electrical Connected Cable Assembly). The resulting downhole assembly for directional drilling commonly includes the downhole motor with bent housing, non-magnetic spacers and survey tool (Fig.3). Survey tools utilising acoustic and electromagnetic communication means are also available.

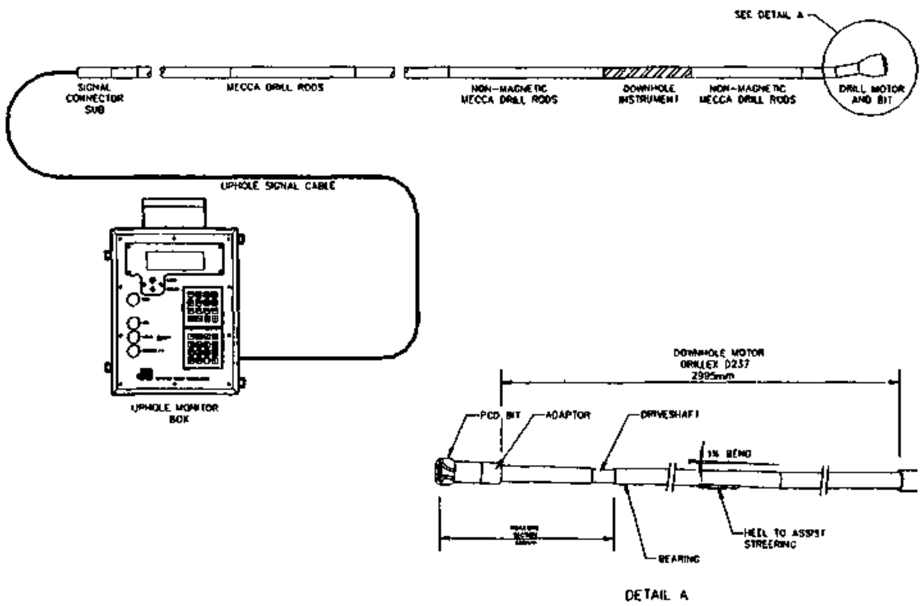

Figure 3 - Schematic survey tool configuration and downhole assembly.

In most cases drilling is carried out across the proposed longwall panel and development roadway at drill spacings and angles determined from empirical data (Fig.4) related to coal seam permeability, length of drainage time available, and gas content. Drilling patterns are largely governed by drill rig access, efficiencies associated with site moves and these gas flow issues. They may be regular and symmetrical (Type A), originate from the same source without branching (Type B), or deviate from a primary hole by branching (Type C). Drilling hole length and patterns are determined more from drainage requirements (principally time needed - or available - for drainage) than by any limitations to drilling technology.

An alternative approach involves drilling very long holes parallel to proposed development roadways (Type D) and long exploration holes designed to maximise drainage time (Type E). This latter approach is usually a secondary benefit derived from what is principally a geological data gathering exercise. Obviously a key disadvantage of drilling very long holes for gas drainage is the very real possibility of the hole becoming blocked not far from the collar thereby negating any gas drainage benefit.

In Australian conditions it is normal practice to carry out drilling for gas content sampling ahead of development drivage. These holes are normally drilled by a small capacity rotary rig to depths usually up to 100m. The objective is to ensure that pre-drainage has successfully lowered the overall in-seam gas content sufficient to allow for safe mining.

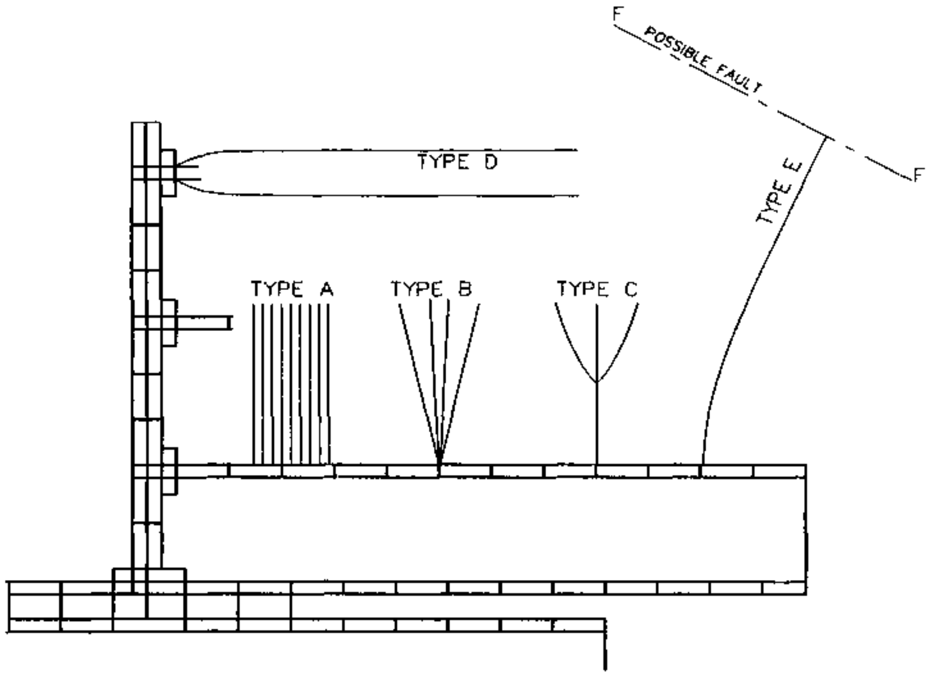

Figure 4 - Typical drill pattern layouts for a longwall operation practicing gas drainage.

The change from a rather chaotic drill pattern (rotary) to a more ordered systematic pattern is reflected in an example from a Southern District Colliery (Fig.5). Here, the more recent drill holes are straighter and more evenly distributed. Previously major deviations were experienced utilising rotary drilling and very uneven gas drainage was the result. The implementation of directional drilling has, in this case, resulted in a judgement that the need for short holes ahead of development for gas content testing purposes is not as great as in the past. The mine has ^ consistently achieved its gas drainage objectives with the advent of directional drilling.

Directional drilling provides benefits in investigating possible geological structures. The ability to navigate the drill string, deviating left, right, up or down, enables a competent operator to explore the strike, magnitude and nature of geological bodies in a way that is simply not possible utilising rotary drilling. In the latter case mis-interpretation of structures (intersected by rotary drilling) as normal floor or roof material has resulted in some extremely costly planning errors that have had a disastrous effect on mine productivity (eg. Tahmoor LW14 dyke/sill complex, 1995).

The advent of controlled directional drilling for pre-development drainage and structure detection has to date apparently been a success. No large outburst events have occurred in Australia during development mining for a number of years.

3.3 **Drilling to mitigate gas-outs on the longwall face**

During longwall mining it is not an infrequent occurrence in gassy seams to halt production in order to allow ventilation to clear gas permeating from the goaf area into the working face. High levels of explosive gas in an environment charged with coal dust and a number of potential ignition sources is clearly a major safety hazard.

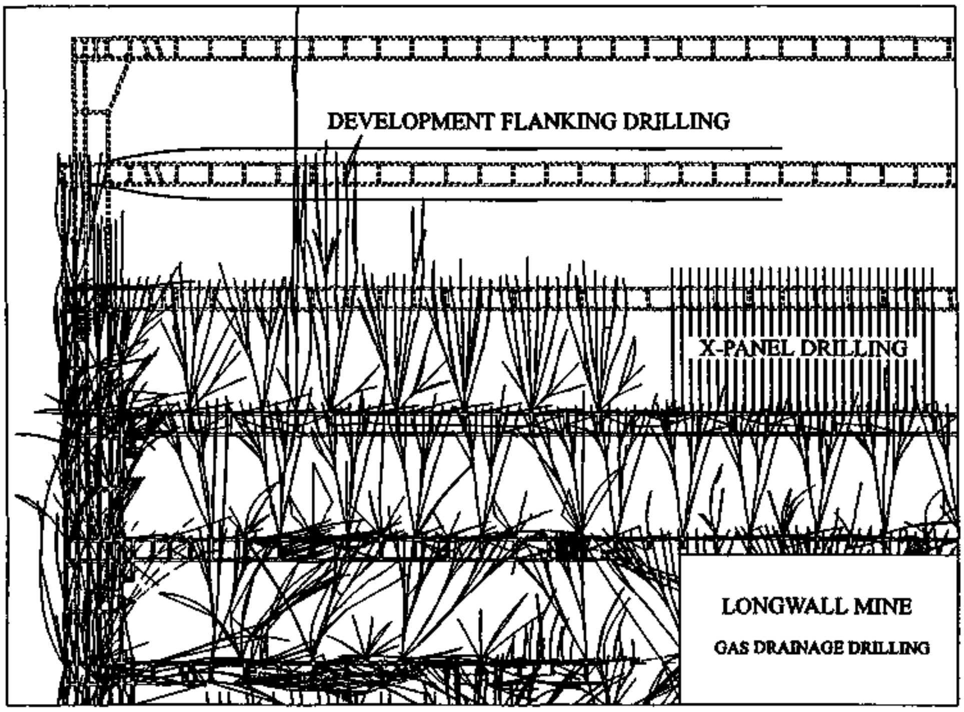

Figure 5 - Example of drilling pattern for existing longwall operation.

In many cases this gas is not derived from the pre-drained working seam but from other gas reservoirs in the roof and the floor. The problem may be overcome by "after the event" ventilation means but commonly drainage methods utilising drilling need to be employed. In shallow workings drilling from the surface may be used to extract the gas, alternatively cross-measure drilling above and below the seam is required.

Typically cross-measure holes target the gas bearing zones in the roof and floor. Like pre-development drilling, drill patterns are largely determined from empirical experience although some semi-quantitative evaluation techniques are available (Lunarzewski, 1995). Holes may be drilled into the roof or floor parallel to the axis of the longwall, or from side cut-throughs normal to the longwall axis (Fig.6).

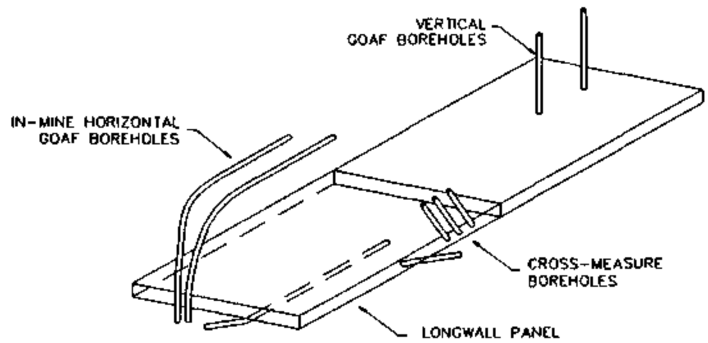

Figure 6 - Cross-measure drilling for goaf drainage and minimisation of longwall face gas-outs.

Holes are placed under suction in order to maximise gas extraction. Again, factors such as strata permeability, presence or absence of natural breaks or passage-ways in the rocks, and hole integrity play a significant role in the effectiveness of the technique. Results to date have been mixed and the methodology requires substantial on-site trials and modifications to meet required objectives. Total removal of face gas outs due to gas emanating from the goaf has not yet been achieved in Australian coal mining.

4. CONCLUSIONS

Drilling has proved highly successful in alleviating the risk of outbursts in Australian coal mining. Cross-strata drilling to avoid face gas-outs during longwall mining has provided some limited success but will need to be subjected to further study and experience to achieve the consistently required outcome.

In-seam directional drilling has enabled more systematic and successful gas drainage and greater flexibility in the evaluation of structures. Improved gas drainage and greater confidence in structure detection has improved mine planning and reduced the risks of operating in gassy mining conditions to Australian operators.

5. ACKNOWLEDGEMENTS

Those involved in underground mining in gassy conditions in Australia are all well acquainted with the concept of drilling for increased mine safety. The ideas presented in this paper are derived from the collective experience of many individuals actively pursuing intelligent solutions to outburst risk and increased drilling productivity. Those who have particularly helped by reviewing the manuscript and offering their suggestions include Frank Hungerford and Paul Maddocks of AMT Drilling Australasia Pty Ltd. Richard Walsh of West Cliff and Wayne Mulholland of Tahmoor have been particularly helpful sharing their experiences of drilling for exploration and gas drainage.

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