The "RIMDRIL" system - Application of horizontal drilling and RIM for the detection of outburst-prone structures

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INTRODUCTION

Productivity and safety are essential requirements for the successful extraction of coal (and gas) in the modern mining environment. This paper deals with two advanced exploration techniques which in combination provide a powerful tool for assessing structure ahead of the mining face (the RIMDRIL system). This information can be used to increase productivity and safety through improved definition of geological structure prior to extraction.

The link between seam structure and sudden release of stored gas energy as an outburst has been well established. The use of RIM (the Radio Imaging Method) and longhole drilling offers the opportunity to assess the likelihood of intersecting these structures prior to development mining and thereby reduces the risk of an unexpected outburst occurring.

The combination of longhole drilling and RIM enables the sensitivity of electromagnetic (conductivity) differences in the seam to be related to drilling intersections and absolute surveyed data in the borehole. The combination requires two sub-parallel boreholes up to 300m apart, and results in the production of an areal coverage of the target area by the use of tomographic imaging.

BACKGROUND

Current status of longhole drilling technology

Directionally controlled in-seam boreholes are regularly being drilled in Australian coal mines from 500-700m and occasionally up to 900m dependent upon local conditions and drilling expertise (Hungerford, 1991). Progressive surveying is used to monitor borehole trajectory and azimuth, with the Eastman single-shot wireline camera the most common tool in use. Cableless electronic survey tools are well advanced but are expensive and have at this stage only experienced limited testing in production mode.

Currently, depth capacity is limited by the problems of in-hole friction and associated surging feed rates. These spikes in the torque loading at the bit may result in stalling of the down-hole motor and subsequent lack of progress in the hole.

Variability in operator performance remains a problem area in that there are only a few very experienced drilling supervisors in the country. Development of this resource is essential for continuing improvement in drilling performance. Attention to training programs and developing drilling experience, establishing systems for recording and reporting information and the elimination of drillers who take unnecessary risks are key elements to improving operator performance.

In the exploration context, the key issue for longhole drilling is making sense of the behaviour of the rig and cuttings through intersected structures. This is highly dependent upon the skill of the operator and a function of such factors as survey interval, magnitude of the feature, sampling rigor and rig performance. Longhole drilling can usually be used to establish major features but is weak on defining faults of less than seam displacement, sedimentary washouts or rolls, and "all-coal" structures such as mylonite zones and strike-slip faults. It is in the definition of these smaller, possibly outburst prone, features that the use of the combined RIMDRIL system can be used to best advantage.

The Radio Imaging Method (RIM)

The Radio Imaging Method has been utilised in Australian coal mines for the past 3-4 years. In that time it has found a niche as an in-mine technique, used for high resolution structural definition within longwall panels, utilising gateroad access. The technique uses medium frequency (50-520 kHz) radio waves and the waveguide properties of a coal seam to investigate seam conductivity variability. For more detailed treatment of the in-mine RIM method refer to Thomson *et al.*, (1990). It has proved to be extremely sensitive to variations in seam conductivity. This has enabled it to be used for the definition of even very small structures as well as major features.

The key to its success in detection of faults is the relationship between water content in structures and conductivity. Dykes are even more apparent due to their conductive alteration halo and associated cinder. Water-filled structures are more conductive than 'normal' coal and thus provide a readily apparent anomaly which may be tomographically imaged or simply determined by individual ray path analysis.

An example of the use of tomographic imaging procedures to investigate an in-seam structure is presented in figure 1. In this case a thrust fault zone in the Bulli Seam has been identified extending across a longwall block at a low angle. This fault was outburst prone, and varied in throw from 0.14-0.2m. Analysis of individual ray paths may also reveal the location of structures (figure 2). In this case, the major increase in signal attenuation rate can be attributed to an outburst-prone dyke, also in the Bulli Seam.

NERDDC Program on in-seam borehole RIM

The recognised capacity of in-seam RIM to detect structure needed to be applied to coal ahead of the face rather than to an already committed longwall block. A NERDDC funded study administered by Australian Coal Industry Research Laboratories (ACIRL) was established to investigate a means of applying RIM from horizontal boreholes to a virgin coal area. The study involved equipment development by Stolar Inc. (now RIMtech Inc.) of the USA, theoretical studies by Macquarie University, image processing development by the CSIRO Division of Radiophysics and the development of an insertion technique by ACIRL. METS (Mine Exploration and Technical Services) took part in field trials and are the current sole licensees of the RIM equipment.

The NERDDC program established that horizontal borehole RIM could be undertaken at moderate hole depths (up to 165m). The limitation applied to how far the casing and pulley system could be inserted by hand. Subsequent horizontal hole tests by METS have encountered the same upper limit to man powered casing insertion. Friction of the casing against the hole and tangles in the string-pulley limit the increased depth capacity. Further depth could only be achieved by use of a drilling rig to power the casing to the required depth, and to extract the casing when completed.

The RIM results from the NERDDC program were positive, indicating clear ground through an area devoid of structure in the Bulli Seam at Tower Colliery, and identifying a dyke in the Bulli Seam at Tahmoor Colliery (figure 3). In this latter case the orientation of the dyke was parallel to the holes rendering it a difficult imaging proposition. Nevertheless, application of the CSIRO Radiophysics hypothesis testing system (Young *et al.*, 1992) produced an image entirely consistent with the geology.

The NERDDC program had proved that RIM could be applied from horizontal holes successfully. The clear task ahead was to improve the logistics of the operation and increase the depth capabilities.

IMPEDIMENTS AND LIMITATIONS

The obvious impediment to more universal application of the RIMDRIL system is the insertion technology. RIM capabilities to 365m depth are currently available in Australia and there are plans to increase depth capacity of the RIM equipment by extending the fibre optic cable to 800m. This is not only required for potential coal applications but is in demand for metalliferous applications of borehole RIM. Given existing cable limitations it should be feasible to investigate the geology in detail up to 350m ahead of the face.

METS are currently investigating the use of water pressure to drive the RIM probes to the end of the hole. This will require a system which allows for water flow through the middle and around the outside of the casing. This system negates the need for pulleys, kevlar string and the tangle problems that this implies. On the downside, water will be required on site and a means to power the casing into the hole other than by hand will be required. It is suggested that this should be done by a drilling rig at the completion of drilling and either the casing sacrificed or retrieved by designing casing which has a thread similar to conventional drilling rods.

Another potential flaw in the system is the implied relationship between gas and water. In other words, a marked RIM anomaly may imply high water content but not necessarily gas. Conversely, high gas content and no water could be potentially missed. Experience suggests the latter case would be rare, and that the RIMDRIL system will err on the conservative side, picking up benign structures in addition to the targeted outburst prone structures.

The range of the RIM equipment in a horizontal borehole arrangement is up to 300m from transmitter to receiver. This is more effective than vertical hole RIM and capable of far greater structure resolution through the use of multiple ray paths. Range is dependent upon seam conductivity, the contrast between floor/roof interface and coal, and seam thickness, quality and rank.

Scheduling of the RIMDRIL operation with the mining cycle requires careful planning. Setting up a longhole drill and associated electrical, ventilation and water requirements needs to be co-ordinated with mine operations. In addition, round-the-clock drilling may be required to minimise the disruptive effects of the operation.

APPLICATION OF THE RIMDRIL SYSTEM

The RIMDRIL system utilises the respective strengths of an electromagnetic geophysical sensing technique and physical measurements made possible by drilling intersections through structure.

The strengths of drilling are that it provides reliable absolute point data in the form of survey intersections, and continuous, linear exploration information through the flow of water and chips from the hole. In addition, monitoring water pressure and feed rates may help to define potential problem areas.

After the hole is completed, on-line gas monitoring can be used to further assess the likely impact of mining through the zone and some preliminary gas drainage can be carried out.

The weakness of drilling alone is its inability to detect small features and those located off the path of the drillhole. This is where the capabilities of the RIM system can be used. RIM can be used from borehole to borehole or borehole to workings, to create a tomographic image of the conductivity of a block of coal. RIM's sensitivity to even small changes in the variability of conductivity encountered in coal seams will provide a high confidence interpretation of geological structure for a block of coal up to 350m x 300m wide (up to 400,000 tonnes of coal). As current limitations to depth capacity of the fibre optic cable are overcome, it will be possible to evaluate up to 700-800,000 tonnes of coal between a single pair of boreholes.

Applications of the RIMDRIL system are twofold, as an early warning device ahead of development drivage, or as an evaluation tool of 2-3 longwalls ahead of the current one. A third possibility is the use of borehole to roadway RIM utilising a single hole from a development roadway to a parallel in-mine face.

Using RIMDRIL ahead of development may be done by drilling holes from opposite sides of the development drive, parallel and up to 350m ahead of the face. Holes may be spaced between 70-150m apart. This arrangement is presented in figure 4. In this way outburst conditions would only need to be worked during development when structurally disturbed ground has been identified ahead of the face by the RIMDRIL system. This approach is particularly relevant to those longwall mines which do not have an established gas drainage program in place.

The more obvious use for RIMDRIL is in establishing the integrity of proposed longwall blocks up to 400m ahead of current workings. This can be done by a series of parallel holes separated by up to 300m, which extend into the virgin coal to the limit of current RIM depth capacity. The number of holes needed is dependent upon knowledge of local geological conditions and degree of insurance required by the mine. This arrangement is also presented in figure 4.

CONCLUSIONS

The combination of point and linear exploration information from horizontal hole drilling and areal coverage by electromagnetic wave propagation (the RIMDRIL system) provides a powerful tool for detecting outbursts and other structural zones ahead of the face.

The system may be used ahead of development drivage, or from existing longwall roadways. Up to 800,000 tonnes of coal may be evaluated using a single pair of holes and with cross-hole tomographic imaging.

The technique can be used to significantly reduce the risk of an unexpected intersection of an outburst feature and improve productivity and safety in gassy mines.

ACKNOWLEDGMENTS

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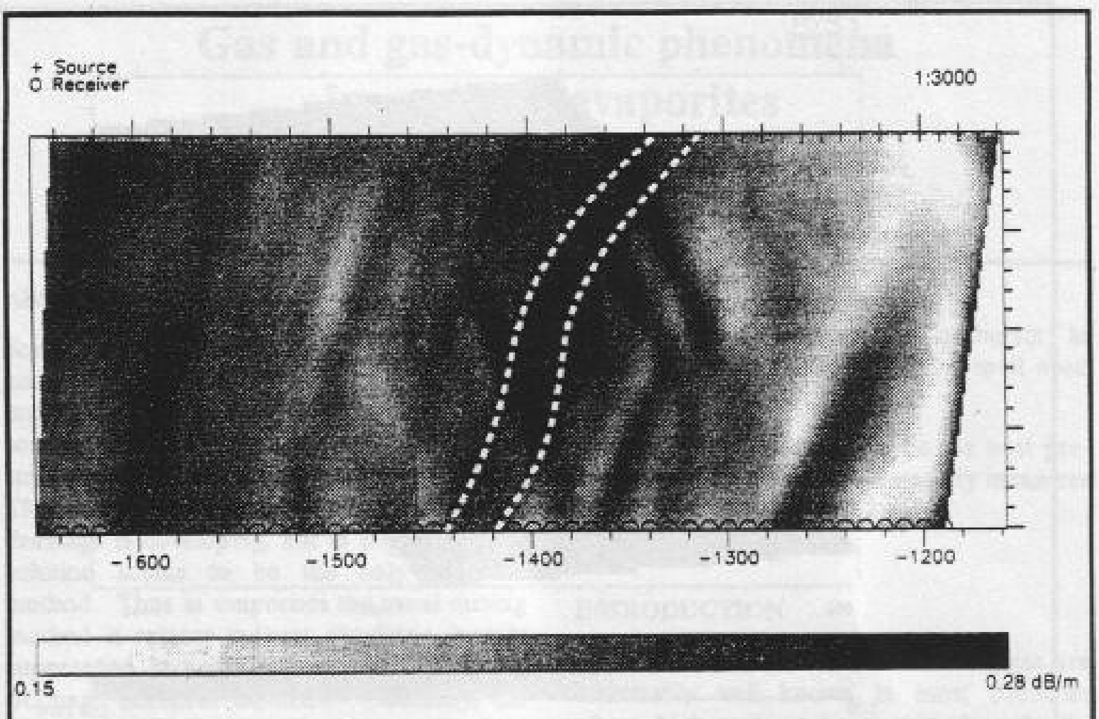

Figure 1. **RIM image through a small thrust fault zone (0.14-0.2 m throw) in the Bulli Seam.**

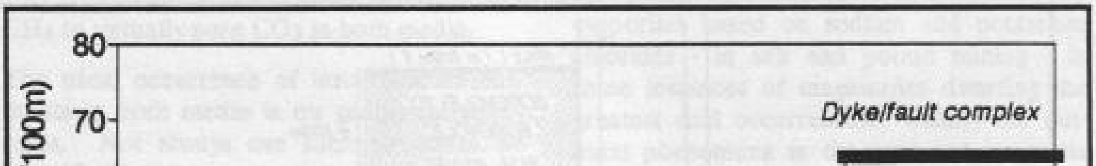

Figure 2. **RIM ray paths through structure.**

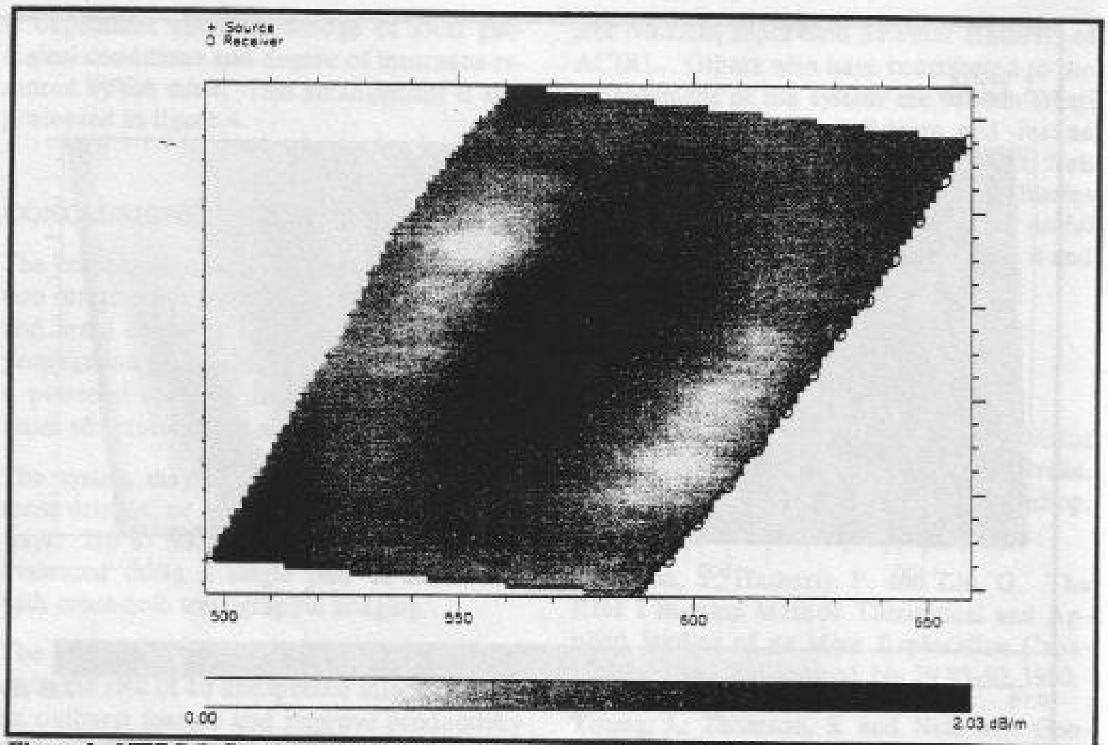

Figure 3. **NERRDC RIM image of dyke striking parallel to drill holes.**

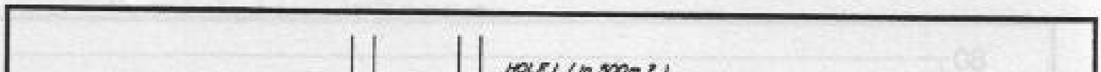

Figure 4. **Various RIMDRIL scenarios - borehole to borehole or borehole to face.**