The day that man harnessed the beast to share his burden, the pursuit to improve productivity began in earnest. With the advent of the steam engine, the industrial revolution created a quantum leap in human output and our standard of living. Information technology (IT), coupled with advanced technology, has again accelerated productivity. The impact of this extends beyond the office, including in the mine.

This article addresses how the integration of IT with exploration technologies can reduce the miner’s burden and increase output. Software applications of advanced geologic modelling can now produce 3-D and 4-D images, with the fourth dimension in real time. The benefits are measurable and include reduced risk, improved health and safety, higher productivity and better financial performance.

Imaging the coal seam

Probably the most significant operational risk in coal mining is probably dealing with the unknown factors, such as the location and size of geologic anomalies hidden in the reserve. This risk increases as mining operations become larger in scale and move deeper into the earth. In order to adequately assess the geologic and mining hazards that may be encountered, mining engineers seek greater information than borehole data can provide.

Standard practice for using exploratory drill holes is to assume that each hole has a radius of influence of 0.25 miles. Within this radius, the coal seam is projected to have physical properties equal to that part of the seam drilled through. However, the obvious question still remains: does that one hole really provide the data needed to reveal anomalies within the measured distance, or is it possible that anomalous conditions may exist just inches away? Exploration holes certainly identify and confirm a property’s potential for mining based on a statistical analysis of the borehole pattern. However, to adequately deal with the risks of confronting sandstone channels, dikes, faults, etc., a small sample of boreholes cannot pinpoint a troubled area unless they are actually drilled into the formation. Certainly, more information than a coring with an area of perhaps 1.61 m² (25 in²) is needed to represent conditions of 125 acres.

Fortunately, technologies exist that provide information beyond the borehole. One such system, the radio imaging method (RIM™), is based on electromagnetic (EM) waves at radio frequencies and a geologic regime’s effect on its propagation behaviour. Since its introduction into mining in

A clearer image

Glenn G. Wattley and Joseph T. Duncan, Stolar Horizon, Inc., US, explain how information technology can be used to produce geologic images, thereby improving productivity and reducing risk.

Figure 1. RIM tomographic image of a longwall coal panel.

Figure 2. Downhole RIM IV being used in a vertical borehole.
the early 1980s, over 500 surveys have been performed in the US, Canada, the UK and Australia. Coal seams act as waveguides for low-frequency EM waves (20 kHz - 1 MHz), and any changes in an EM wave’s signal strength or phase position can provide the data needed to identify and locate geologic anomalies. The data, processed through tomographic inversion modelling, can provide 2-D and 3-D images of the coal seam and any anomalous zones that it may contain (Figure 1).

The industry trend is to mine wider faces (approximately 1100 ft) and longer panels (over 15,000 ft) to improve longwall productivity. The greater surface area of a mining face provides greater production to amortise fixed costs such as equipment investment and setup, but larger panels greatly increase the probability of encountering anomalies. Based on Stolar Horizon’s database at the Stolar Global Center for Geologic Interpretation (SGCGI), on average a coal seam anomaly is encountered every 1000 ft within a longwall panel. In 20% of these cases, the anomaly is serious enough to reduce or stop production. In fact, many mines have experienced costly interruptions of production because of bad, unforeseen geologic conditions.

To reach the wider panels, the RIM equipment has been upgraded (RIM IV). This makes it possible to traverse the width of most panels (capabilities up to 1800 ft) and to use the signal’s phase-shift information to improve its signal-to-geologic noise (S/N) ratio. The combination of a high S/N ratio and the ability to process phase shift and signal strength means that RIM images can be produced with greater resolution than ever before.

Fortunately, IT and software models have developed alongside the need for enhanced imaging. Formulated by researchers at Sandia National Laboratories, a Full-Wave Inversion Code (FWIC) software-modelling package can be used to process data collected on RIM IV surveys. FWIC processing creates the highest resolution 3-D images available for RIM data. The practice of such imaging is already common in the oil and gas industry. The use of IT tools greatly improves the picture of the coal reserve, which will greatly improve the mining engineer’s mine plan and avoid costly encounters with anomalies.

In addition to enhancing the images and content of 3-D RIM, the IT revolution is reducing the time it takes to process survey results. Notebook computers and the Internet are truly ‘shrinking’ the world. At the SGCGI, a virtual organisation is able to save considerable time in delivering results.

**IT in action**

In two recent assignments, considerable time was saved, providing mine management with critical geologic information for immediate operations decisions by mining face provides greater production to amortise fixed costs such as equipment investment and setup, but larger panels greatly increase the probability of encountering anomalies. Based on Stolar Horizon’s database at the Stolar Global Center for Geologic Interpretation (SGCGI), on average a coal seam anomaly is encountered every 1000 ft within a longwall panel. In 20% of these cases, the anomaly is serious enough to reduce or stop production. In fact, many mines have experienced costly interruptions of production because of bad, unforeseen geologic conditions.

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**View of the future**

Too often, a thorough assessment of geology is neglected until it is too late. Over the past few years, there have been several examples around the world where the advance of a longwall shearer was slowed considerably or stopped altogether due to uncharted anomalies and faults. Finding a sandstone channel in a longwall panel after the shearing machine has started mining on the face is an expensive and disheartening experience. A more cost-effective exploration program in advance of mine planning can establish a more comprehensive understanding of the reserve.

To develop reserve information as early in the process as possible, RIM surveys can be conducted downhole well in advance of mining (Figure 2). Many such surveys have already been carried out. Downhole surveys have proven to be cost-effective in identifying and locating geologic anomalies and abandoned mine workings.
within coal seams. Such techniques can establish the integrity of barrier pillars; the recent underground flood at the Quecreek Mine in Western Pennsylvania, US, has highlighted the need for a serious evaluation of the process of reserve definition. Governor Mark Schweiker’s Special Committee investigation into the detection of old mine works has made many recommendations in this area.

With the increase in drilling for coalbed methane (CBM), new opportunities exist for enhancing reserve information. The trend is to perform directional drilling from the surface with horizontal holes mid-seam. Horizontal holes will enhance CBM recovery without sterilising the seam. Advanced guidance and detection tools are being developed and tested to work with existing RIM probes for crosswell imaging. The benefit for mine (or oil and gas) planners is that the CBM operation can be viable and profitable with new technology support by IT. In the future, a complete assessment of the reserve (seam thickness, anomaly locations, etc.) will essentially be provided as a free byproduct of CBM drilling.

The logging of geologic data will be ‘information intensive,’ i.e. critical communication and data processing will take place. A CBM guidance unit called the Drill-String Radar (DSR™) will be a ‘measurement while drilling’ (MWD) tool (Figure 3). Using the DSR on a drill string just behind the downhole drill motor, enables critical geologic data such as coal seam thickness and roof and floor structure to be measured in real time. Results have indicated that the DSR with MWD capability will reduce wellhead cost by up to 45%. In a case study of a project at a western US field, wellhead costs fall from approximately US$ 1.05 to US$ 0.57/million Btu. Up to 30% of the drilling cost reduction will be realised by keeping the drill string mid-seam. The other 15% will be realised through enhanced recovery.

In addition, the MWD data (collected in real time as the fourth dimension) and crosswell RIM signals can be used to develop 3-D images of the entire property prior to final mine planning efforts. Considerable risk reduction will take place when mining engineers are provided with such complete reserve information. Longwall panels will be designed to avoid major faults, igneous dikes and sedimentary channels. With more accurate reserve definition, more appropriate equipment selection can be made, all driven by enhanced IT equipment and software.

One final benefit of using enhanced IT and advanced technology for better planning and risk reduction is that the financial community will respond with better terms of investment. Future projects may indeed find it difficult to secure funding if the risk associated with geology is not adequately addressed.

Conclusion

The advancement of geologic investigative technologies coupled with upgraded IT software/models and hardware has had a significant impact on improving the quality of geologic intelligence. This improved knowledge greatly reduces risk and improves operational and financial performance. Advanced RIM systems and the SGCGI are delivering greater intelligence in less time, so mine management can make more informed decisions. With CBM, the DSR reduces wellhead cost and provides useful seam information for future mining activity as a free byproduct. The advancement of IT is paying off in the mining industry.

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REAL-TIME AUTOMATION REQUIRES SENSORS TO DETECT CHANGING GEOLOGIC SEAM CONDITIONS

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