Coal Geology Where to From Here?

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INTRODUCTION

Coal geologists are under pressure to minimise exploration expenditure, maximise interpretation confidence and produce the results often too soon. This pressure continues to increase as companies are forced to evaluate borderline economic deposits which are usually deeper and more hazardous, such as the Togara North and Togara South projects in Central Queensland.

In response to this pressure, coal geologists are having to integrate and utilise every piece of information available including stratigraphic, structural, analytical, geophysical, geotechnical, hydrological and more recently, environmental data. In Australia, coal geologists rely on research to continually improve both data acquisition and data interpretation. Some of these developments are discussed as well as suggestions for improvements in other areas within this paper.

Following the application of modelling and remote sensing issues integral to the successful evaluation and development of coal mines, the long, medium and especially short term production factors dominate the applied mining geologist's time to a far greater extent than the development of an understanding of the mine geology.

The primary factors to be considered by the mine geologist include:

- The accurate short term modelling of mining blocks for drill and blast, reserves and reconciliation;
- The accurate delineation of in-pit structure, particularly seam splits, rolls, wants, faults and intrusions;
- Provision of accurate and relevant geological and geotechnical information to all levels of mineworker, from the general manager to the engineers, foremen, operators, coal handling preparation plant (CHPP) personnel and owners; and
- Accurate pit reconciliation to establish coal loss and dilution leading to better pit control and continuous improvement.

DRILLING DATA

As drilling budgets have tightened, one of the lessons coal geologists have learnt in the past decade is that every drillhole counts and every piece that can be extracted from the drillhole must be recorded and utilised.
Logging drill core today involves recording:

- Lithological descriptions relevant to impact on mining conditions eg. strength, state of core, and bedding.
- Geotechnical data such as rock quality density, fracture and joint locations, nature of breaks, and mineralisation of joints.
- Water flow rates and standing water levels.
- Any anamolies that occur during drilling eg. loss of circulation, gaseous odours, and hole caving. These should be noted on geological hazards maps.

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Core photography ensures a permanent record of drill core for reference by mining professionals for blasting, equipment selection, trafficability, roof bolting and mine design.

Advances in digital photographic equipment will allow geologists to include core "photographs" in geological reports, on borehole stratigraphic profiles and cross-sections. As the resolution of digital cameras increase, geologists will be able to exam core photographs in detail, zoomed in on their computer workstations.

Coal geologists can perform a number of tests on-site on fresh core as apparatus becomes compact. Tests include:

- Gas desorption testing to ensure minimal loss of gas over time.
- Point load UCS tests.
- Downhole geophysical logging recorded in an international standard digital format.

Geophysical logs have become an essential tool in the evaluation of coal deposits as they provide information on

- Accurate seam and interburden stratigraphy;
- Detail correlation of seam splitting;
- Geotechnical data – fracture and rock strength; and
- Structural information – Sirolog can determine coal ash content and a variety of elements including Fe, Ca and Si.
- These data can be readily incorporated into geological database systems and utilised for detailed geological interpretation including:
- Cross-correlation of logs with analytical results.
- Cross-correlation of logs with geotechnical results.
- Seam splitting correlations on cross-sectional and 3D borehole displays.
- Interpretation of the lithologies in chip drill holes.

Chip drill holes can now be automatically interpreted using neural network technology. This system learns geophysical log responses for detailed cored drill holes and then applies this knowledge to the geophysical logs for chip drill holes (Fig. 1).

Artificial Intelligence (AI) has also been applied to correlation of drill hole lithologies (Fig. 2), designing open-cut and underground mines as well as optimally scheduling mines to meet product tonnage and coal quality targets for multiple markets

GEOTECHNICAL INTERPRETATION

Cross-correlation of UCS strength measurements with downhole sonic logs gives a continuous record of rock strength down each drill hole. This information can be used to evaluate roof and floor conditions across the deposit by modelling cumulative UCS over one metre intervals of roof and floor strata. The resultant maps clearly indicate zones of relatively weaker and stronger strata which will help determine roof bolting requirements and areas where productivity may be affected due to difficult conditions.

The same data can be utilised in open-cut mining by evaluating the change in strengths of interburdens and overburden across the deposit. This will provide valuable information for blasting requirements and ripability.

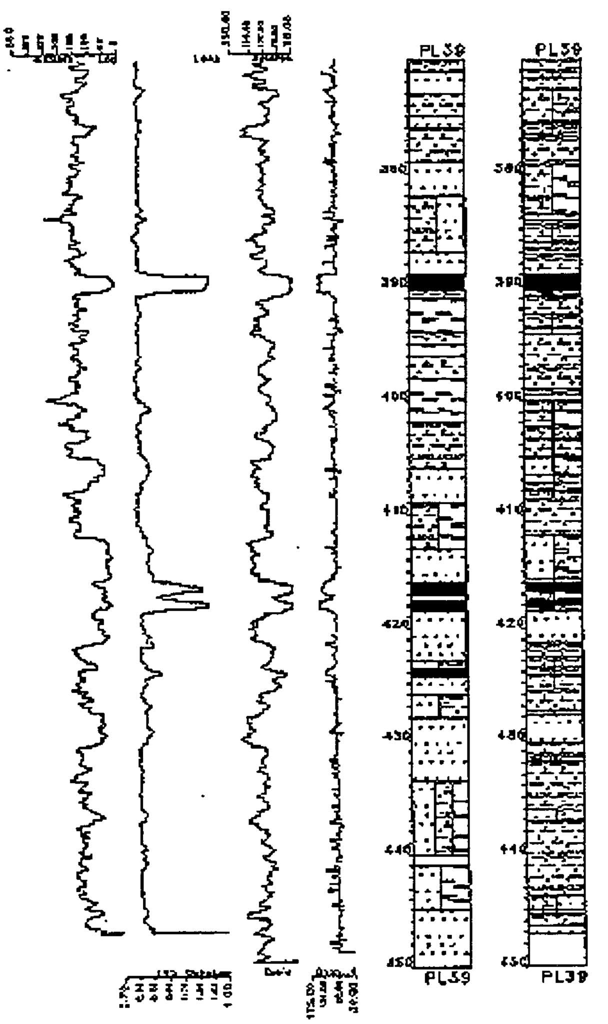

Fig. 1 - Comparison of logged open hole lithology with AI interpreted lithology

SURFACE AND SUB-SURFACE GEOPHYSICS

Coal geologists are finding valuable information from the interpretation of geophysical surveys. This is due to two recent developments, the ability to record high resolution data and the advances in interpretation software.

Image processing of high resolution aeromagnetic and ground magnetic surveys is proving invaluable in the structural interpretation of coal deposits as well as delineating igneous bodies. Images are enhanced by superimposing SPOT data as well as for gridded model seam surfaces derived from borehole data.

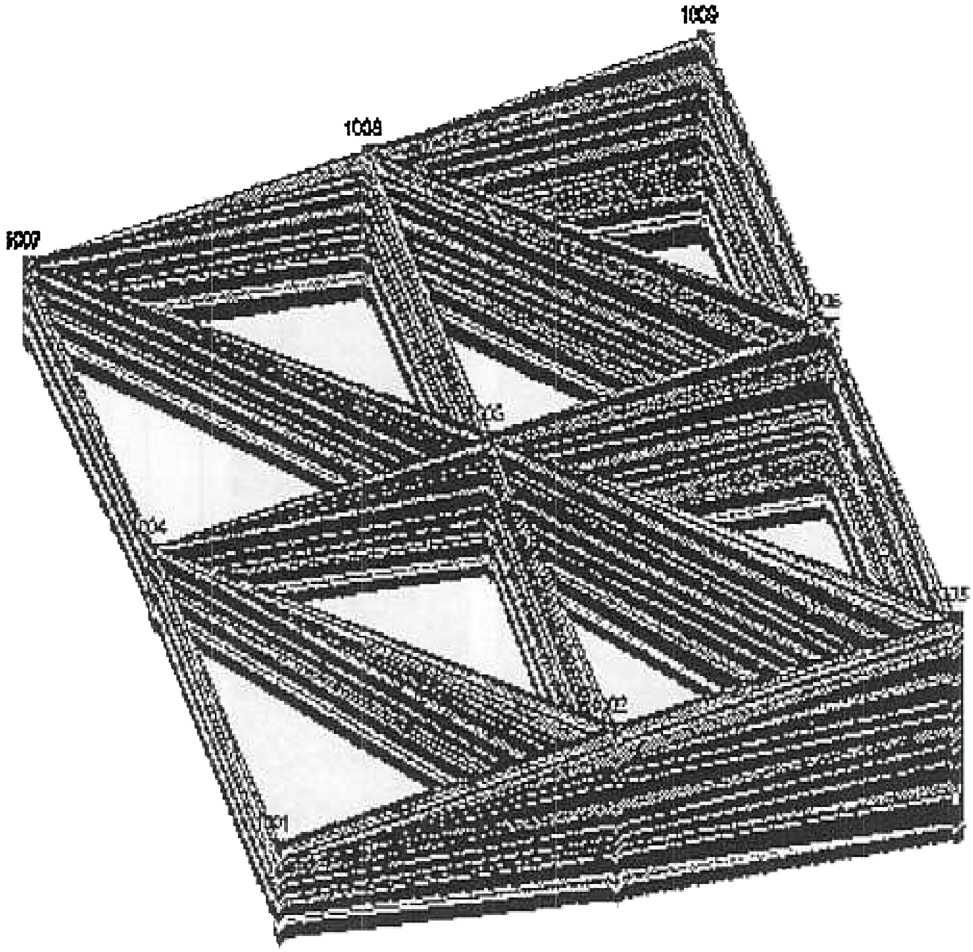

Fig. 2 - 3D Geological Fence Diagram using AI Correlation

Improved methods of filtering and displaying data have given geologists a clearer picture from which to interpret structural geology.

Surface seismic surveys have also undergone improvements in areas of data collection and interpretation. Today, seismic surveys in Queensland coalfields are confidently delineating faults with as little as a 2 metre throw. The major limitation of 2D seismic surveys, that is, determining the orientation of faults, has been overcome with the development of 3D seismic surveys in recent years. Although regarded as an expensive tool, 3D seismic costs would total less than 10% of the costs a company would suffer in an area riddled with small faults and bad ground conditions.

The major portion of 3D seismic costs is in drilling shot holes to below the depth of incompetent material. Research programs are underway to develop a cheaper and faster form of seismic source such as high frequency vibrators which are being designed to produce a stronger and clearer signal from the surface using a track-mounted compact and versatile vehicle.

Seismic interpretation software has undergone extensive improvements in recent years. Using downhole geophysical sonic logs, a synthetic seismogram (Fig. 3) can be computed, and subsequently be positioned on a seismic section using horizon markers such as seams for references. The borehole depths are then used to accurately convert seismic time sections to depth sections. Major coal seam reflectors can be automatically traced and converted to real depths, producing digital geological cross-sections which can readily be integrated into a model structure surface.

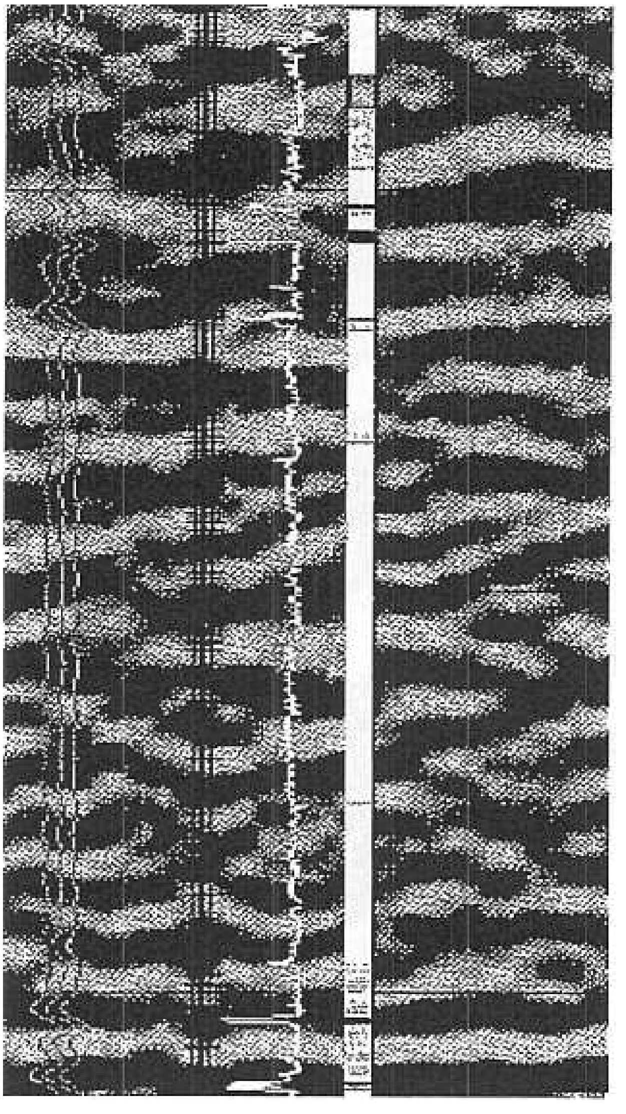

Fig. 3 - Synthetic Seismogram

SHORT TERM MODELLING

To adequately model the short term requirements of an operating mine, or one commencing operation, it is assumed that an adequate and integrated modelling, coal quality, survey, scheduling, simulation and reporting package is in place. Without such a package, needless time is lost in data formatting, exchange and rehandling which causes losses in time, expertise, money and efficiency.

An adequate short term model implies a reasonably adequate long term model incorporating the above mentioned components. This is where the GIGO (garbage in - garbage out) principle applies, where inadequate information and poor data collection will produce a poor model.

In today's world the buzzwords are "best practice". Many operations do not enjoy the full benefit of the information they now have available nor are the workers often able to realize their full capabilities due to outdated methods, the "we've always done it that way" attitude, lack of resources e.g. computer power and software, lack of management focus and mine equipment limitations.

Best practice in the future will include on-line, real time data acquisition from blast drills. The drilling of a blast hole involves the parameters of weight on bit; in coal mining this equates to pull-down, rate of penetration, rotary speed, rotary torque, bit size, type and jet size and the air pressure/volume. These factors may be combined to provide a drilling exponent, similar to that calculated from parameters used in drilling oil - gas wells. Drilling exponents, especially from such a small area as a coal mine usually defines, can be correlated to determine rock type and depth markers, to avoid drilling into, or too close to, coal seams. The importance of this to reducing blast damage to coal is fundamental and has been covered by many projects and reports. This information will allow the drill and blast engineer to determine relative rock strengths affecting powder factors, pattern design and blasthole charging.

The real time monitoring of drilling parameters is now possible. Further, other studies currently being undertaken include monitoring while drilling by geophysical logging methods, as practiced in the oil and gas industry and in in-seam drilling. Other projects include the use of bit vibrations to create a seismic model ahead of the drill bit of rock type. The selective and controlled drilling of blastholes to, or into, and in some cases where log - quality correlations exist, through the target coal seams, allows the rapid modelling of the blast pattern to determine drilling depths for the remainder of the pattern together with blasting profiles of the holes for explosive types, decking etc. Pre-split holes are particularly useful as they are generally drilled prior to the main pattern. In areas of rapid geological variation selected main pattern holes may be drilled to coal. Currently, many geologists rely on drillers depths, if available and recorded, drill cuttings analysis, geophysical logging and drill pull-down logs to provide the information to those few who do model these data. Such methods are usually time and labour intensive, leading to less than optimal utilization, if viewed at all. The ability to receive real-time, accurate data for every hole ensures rapid model adjustment and communication to the drill and blast crew. Further, such information will be used in the pit loss reconciliation process.

STRUCTURAL DELINEATION

The accurate delineation of in-pit structure, particularly seam splits, rolls, wants, faults and intrusions follows from the information gained prior to and during the mining process. Primary methods of collecting this information include in-pit mapping and information gained from the drilling and monitoring of blast holes as mentioned above.

In-pit information may be lost due to inaccessibility and/or dangerous conditions. The accurate and timely mapping of highwall faces may now be possible with the application of laser and GPS technology. Faces may be mapped for blast-hole drilling information, the current primary application of this technology which is often carried out by explosive companies. Future applications of this method will result in the precise and rapid mapping of lithological units, structures and seam profiles. These data could then be quickly downloaded, modelled and utilised in pit reconciliation, structural locations, seam location and lowwall locations for the following strip, reducing the likelihood of lowwall edge losses.

Further advances in the delineation of these features may result from the application of seismic data monitoring by long term fixed seismic geophones of defined in-pit blasts, probably from pre-split blast holes. Long term monitoring of this information over varying blocks and benches may yield 3-D seismic models of the strata ahead of the mining face. Correlation of the data with observed pit structures and strata may lead to very detailed images of the proposed mining area ahead of the current coal face.

COMMUICATION

Provision of accurate and relevant geological and geotechnical information to all levels of mineworker, from the general manager to the engineers, foremen, operators, CHPP personnel and owners, together with adequate and ongoing education of all employees is essential to a successful and profitable mining operation. The primary aim of coal mining is to take a geological resource and create a saleable product as efficiently and profitably as is safely and financially possible. The aim is not to provide a scheduling or equipment challenge for engineers, a creative accounting exercise, a research thesis to a geologist nor an industrial relations exercise.

The aim is to provide real-time, online geological, mine design, scheduling, survey and performance data essential to the continued improvement of productive and profitable performance of personnel and hence equipment. This does not mean that the geologist or engineer hides behind a computer or a technical vocabulary at the expense of in-pit production issues.

This technology allows these personnel to spend more time where it is most productive, that is balanced between the books and the coal face and not sidelined in a paper war.

Real-time information may be gained from the use of global positioning system (GPS) on equipment for accurate positioning, e.g. blasthole rigs, particularly when drilling angled face holes. The continuous real-time monitoring of data, be it geological, engineering or production is essential and information will be relayed back to operators by colour monitors including mining method, location, geology, mining horizons, productivity and future tasks. Alternative mining methods may entail changes to dig methods, dozer cleanup and so on to minimise coal loss and dilution.

PIT RECONCILIATION

Accurate pit reconciliation is necessary to establish coal loss and dilution leading to better pit control and continuous improvement. The first step in this process is to know how much coal is available for mining. The accurate measurement of truck loads must be made on an individual load basis, particularly when trucks of different load capacity are used for the same coaling operation. Further, accurate weight measurement must be made at the washery of the run-of-mine (ROM) and clean coal stockpiles and washery balances calculated. Real-time truck loads may be transmitted to the geologist together with washery information. The rapid determination of ROM recovery from mining blocks allows rapid feedback and identification of loss areas. ROM ash levels may be compared to expected ash levels for mining blocks, dilution calculated and action taken to reduce excessive dilution, e.g. better seam clean-up, during the mining process rather than some months later.

Clean coal yield from washed product can be related to ROM feed, affected by dilution and loss of particularly weak bright coals, and in-situ predicted recoveries. Rapid feedback of this information allows the reconciling of yield and ash data to coal losses, dilution to the observed mining operation, the correction of mining technique and equipment utilisation if necessary.

CONCLUSION

With advancements in drilling communication and computer technologies, coal geologists can look forward to a future where field results will be evaluated in real time. It is conceivable that soon, drilling rigs will be equiped with downhole geological logging tools, that will pulsate results to the surface whilst drilling progresses. The results will be conveyed via satellite email communication back to a project office with a workstation using artificial intelligence to convert the results into lithological, geotechnical and analytical data plotted in full colour on a 3D perspective screen display. A drilling program involving numerous drilling rigs would be interpreted, evaluated and re-appraised in real time.