DEVELOPMENTS IN GEOPHYSICS FOR PREDICTION OF STRUCTURES INFLUENCING PRODUCTION IN MINES

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ABSTRACT

In both surface and underground coal mines, the detection of geological structures ahead of workings is recognised as being fundamental to the efficient operation of the mine. Mining into zones of unexpected structures has a drastic effect on a mine’s productivity. For the prediction of structures, geophysical methods can be applied from the air, from the ground, from boreholes and from underground workings.

There are several improvements to report in the geophysical methods being developed for these purposes. These include developments in three-dimensional seismic reflection surveying, cross-hole seismic reflection methods and radar systems. The recent development of the radio imaging method for use in underground mine workings will complement existing in-seam seismic methods. Geophysical techniques for use in horizontal boreholes are also under development.

INTRODUCTION

Fundamental to any higher production coal mining system is the need for advance knowledge of geological conditions. Mining into unexpectedly difficult geological zones can halt production. Knowledge of the locations of zones allows time for appropriate mine planning decisions before production is affected.

Future techniques available to the mine planning engineer for investigating geological conditions will continue to be based on drilling, geological mapping and geophysical surveying. Radically new techniques are not expected to be developed in the immediate future. Rather, significant use of computers and increased maturity in existing methods will occur. Exploration strategies involving the integrated use of techniques will be common. Geologists will be much better versed in exploration techniques and, through the use of computer work stations, interactively develop complete geological models of their mines.

AIRBORNE METHODS

Of the airborne geophysical methods currently available, detailed aeromagnetic surveying is the most useful in coal mining. The most important use of these surveys is for the detection of igneous dykes. Uniform survey coverage of large areas is readily achieved. Magnetic methods respond best to near surface magnetic bodies. Dykes and sills at coal seam depth are difficult targets. Similarly, faults are difficult to detect.

These applications of aeromagnetic surveys are not expected to change in the future.

GROUND METHODS

In most cases, a ground geophysical survey combined with drilling will form the starting point for detailed coal mine exploration. Seismic methods are likely to continue to be the main investigative technique. Reflection seismic surveys, while comparatively expensive, provide the best means of determining coal seam continuity in both open cut and underground mining. Restrictions to the resolution which can be achieved will remain and some sites may still prove geologically unsuitable for seismic surveying. However, there are developments underway which will greatly improve the accuracy and cost of surveying. These include work on:

- real time and field based analysis procedures for improved quality control, quicker turn-around and the ability to modify survey line locations while surveys are underway.
- improved and cheaper instrumentation at all levels - from the hammer seismograph up.
- interactive processing and interpretation.

The AusIMM Illawarra Branch, 21st Century Higher Production Coal Mining Systems—Their Implications, Wollongong, NSW, April 1988 95.
facilities which will allow geologists to become more involved and remove the methods 'black-box' reputation. Interpretations will be made on computer work stations. Improved efficiency and the development of complete geological data bases will result.

- three-dimensional seismic methods which will allow seams to be mapped over a complete area rather than on the present grids. On the work station screen, faults and geological boundaries will be mapped over their full extent.

In addition to these developments, it is confidently expected that seismic methods will find a role in specifying rock mass properties for mine design purposes. Seismic wave information allows the unique determination of the earth's elastic parameters and techniques are presently being developed to extract this information from field recordings.

Magnetic methods will have a continuing role in dyke detection. With new instruments such as the digital caesium sensor based magnetometer developed by the Geophysical Research Institute at the University of New England, sensitivity and survey ease previously unobtainable are now possible. Increased use of such systems can be expected but the fundamental restriction to the detection of near surface igneous occurrences remains.

For the location of sills, electromagnetic sounding is an appropriate technique. Currents induced at depth from loops placed on the earth's surface respond differently to the cindered coals associated with igneous intrusions. Provided adequate allowance is made for near surface cultural and geological features reasonable accuracy can be achieved.

Other electrical and electromagnetic methods which will continue to find a use in coal mine exploration include the resistivity method and the VLF method under development at Griffith University. These methods respond to the differing electrical properties of the near surface layering. Faulting and coal subcrops can be detected, but again, allowance must be made for cultural and other geological constraints. As low cost methods which may be useful to the problem of hand, continued application of these techniques can be expected.

Detailed investigation of subsurface layering by radar methods will become important in open cut mining. The radar method is fundamentally limited to a depth of investigation of only tens of metres, but for exploration over such depths, rapid and very precise mapping will be possible.

BOREHOLE METHODS

Despite the above developments in geophysical mapping procedures, drilling will remain an integral part of exploration. Confirmation of predictions will be required and samples will still be taken for testing purpose.

Given this situation, work will continue on further developing the good use already being made of the access given to the subsurface by drilling. Geophysical well logging is currently undertaken to provide stratigraphic information and to minimize coring requirements. Improved logging which will yield even better stratigraphic, analytical and rock property data can be expected in the future.

Surface boreholes also provide access for geophysical investigation of structures away from the borehole. Radar methods capable of accurate probing a few tens of metres away from the hole are now being developed, the cross-hole seismic reflection technique being developed at the University of NSW and cross-hole tomography methods such as being developed by BHP, Macquarie University and CSIRO Radiophysics all will be increasingly useful. Such methods all allow better resolution than is possible from surface geophysical surveys and will allow extrapolation of geological information away from boreholes, particularly when surface access is difficult or denied as in stored waters and national parks.

Once testing is completed in surface boreholes, sleeper geophones and antennas for subsequent in-seam seismic and RIM surveys can be installed. Many companies are now doing this routinely and the practice will continue.

Underground in-seam drilling is now another exploration method. It is the subject of a separate paper by Williams and Hungerford and is not discussed here. However, it follows that just as geophysical techniques have been developed for vertical boreholes, similar procedures are required to obtain the most information possible from horizontal holes. A logging system was developed by the University of Queensland but never reached production status. This work has recommenced with a MEEDC grant to BP Coal and subcontracted to the University of Queensland and AGILE but much has still to be done. Similarly there is a need for seismic, radar and RIM methods in this situation. Presumably over the next decade these needs will be addressed.
UNDERGROUND METHODS

In-seam seismic and RIM are the most
expensive geophysical exploration
methods in use today. They are
time consuming and expensive because
they require the use of special
equipment and techniques. However,
they provide valuable information about
coal seam structures and underground
targets that cannot be obtained by
other methods.

In-seam seismic methods are based on
the principle that seismic waves
propagate through different material
layers at different speeds. By
measuring these velocities, the
geological structure of the area can be
mapped.

RIM (Remote Imaging System) uses
electromagnetic waves to detect
discontinuities in the ground.

CONCLUSION

Geophysical surveying continues to be one of
the principal means of investigating coal
seam structures and underground conditions.
The techniques can be applied
variously according to the type of mining
operation, the nature of the expected
anomalies, ground surface access, and
the availability of boreholes (vertical
or horizontal) and any underground access.

Significant improvements in most of the
geophysical techniques can be expected in the
future. In addition to these technical
developments, geologists will be better
equipped to devise integrated exploration
strategies. Use of interactive work stations
for interpretation and the development of
ground truth models will be widespread.