Airborne Geophysical Techniques

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AIRBORNE GEOPHYSICAL TECHNIQUES

Mike Armstrong\(^1\) and Allen Rodeghiero\(^1\)

ABSTRACT: Airborne geophysical surveys have been used extensively in the mineral exploration industry predominantly for the delineation of metalliferous deposits. Recent advances in technology and the integration of multiple geophysical data-sets including aeromagnetic, radiometric and gravity surveys can provide useful information on lithology and structure. Additionally advances in data analysis, processing and image enhancement techniques have improved the resolution of geophysical datasets so that very subtle variations in the geophysical responses can be identified.

High resolution aeromagnetic and radiometric surveys have recently been acquired over the Dendrobium mine district in the Illawarra Coal Fields. The primary objective of this survey was to delineate any igneous intrusive deposits that may impact on underground Longwall mining operations. A range of enhancement techniques were also applied to the data to improve resolution and delineate the lateral distribution of sills at depth as well as anomalous features associated vertical/sub-vertical dyke deposits that may or may not reach the surface.

Airborne gravity gradiometer technology has also been successfully used to explore for a range of ore types (iron ore, kimberlites) and for geological mapping. BHP Billiton has successfully demonstrated that the FALCON airborne gravity gradiometer (AGG) can be used over sedimentary basin environments and has detected deep channels in the Gippsland Basin. A survey in the Latrobe Valley successfully delineated the coal horizons (Rose, 2005). Detailed modelling has been completed to determine whether airborne gravity techniques would be useful, specifically for delineating igneous sills at depth in the Illawarra Coal Fields. Some doubts have been raised on the suitability of this technique due to the nature of the topography, depth of cover and the lack of density contrast between intersected sills and the host sequences.

INTRODUCTION

A high resolution helicopter aeromagnetic and radiometric survey of the Dendrobium project area was flown by Fugro Airborne Surveys in April – May 2005 and acquired a total of 4461 line kilometers of geophysical data. The survey was designed to optimise the measurement of the magnetic response from igneous intrusions and structures that could influence future mining of the Wongawilli seam. With a nominal terrain clearance of 40 metres and 25 metre line spacing, the survey produced a high quality data set for the interpretation of the geological features.

In general the magnetic susceptibility or magnetic response of igneous deposits is relatively high in comparison with the sedimentary geological formations in the Sydney Basin. This is due to their content of highly magnetic minerals and in some cases such as the Cordeaux Crinanite (Teschenite) the susceptibility is a few orders of magnitude greater than background. The anomalous feature associated with this deposit is clearly visible in the lower right of Figure 1 and magnetic data from the aeromagnetic survey can be used to map its approximate surface distribution. Other igneous intrusive deposits such as dykes, pipes and sill deposits have comparatively much more subtle magnetic responses and are difficult to delineate from the host geology. In addition the magnetic susceptibilities of field samples from various known deposits in the area have very low magnetic responses and are difficult to distinguish from the host sedimentary sequences. The high magnetic response of the power lines in the centre of Figure 1 should also be noted.

Results from this survey were successfully used to target and define a number of dykes in the area and subsequently resulted in modifications to the proposed mine plan (PMP). This discussion intends to outline the various airborne geophysical techniques used in the Illawarra Coalfields and provides a case study of the recently acquired aeromagnetic and radiometric survey and how the results were used successfully to target and intersect interpreted features with inseam drilling techniques.

\(^1\) BHP Billiton, Illawarra Coal
Airborne magnetic and radiometric surveys have been used extensively in the mineral exploration industry predominantly for the delineation of metalliferous deposits. Recent advances in technology have substantially increased the accuracy and resolution of these techniques so that they can be used to provide useful information on lithology and structure in the coal mining industry. Additionally, advances in data analysis, processing and image enhancement techniques have improved the resolution of geophysical datasets further so that very subtle variations in the geophysical responses can be identified.

The physical principles of this method are based on taking measurements of the ambient magnetic susceptibility of the surface geology and use this data to determine the distribution of magnetic minerals and hence changes in lithology. Igneous deposits generally contain a high concentration of magnetic minerals and the aeromagnetic method was originally developed to remotely detect large subsurface deposits of minable minerals. The advantages of this method are that very large areas and difficult terrain can be surveyed remotely in short periods of time thus making it very cost effective.

Airborne radiometric surveys similarly are used to measure variations in the mineral composition of surface geology and are used to map lateral lithological changes. This method involves the measurement of naturally occurring radioactive elements that exist in rock forming minerals and soil profiles. These elements are Uranium (U), Thorium (Th) and Potassium (K), which can be found as trace elements in all rocks and decay naturally giving off gamma radiation (gamma rays). These gamma rays that are emitted can be measured by a gamma ray spectrometer which can determine the source element by its peak gamma ray energy (Telford, Geldart, Sheriff, 1990).

**SURVEY ACQUISITION AND PARAMETERS**

A high resolution helicopter aeromagnetic and radiometric survey of the Dendrobium mining lease area was flown by Fugro Airborne Surveys in April – May 2005 and acquired a total of 4461 line kilometres of geophysical data.
The survey was designed to optimise the measurement of the magnetic response from igneous intrusions and structures that could impact on future longwall mining in the Wongawilli seam. With a nominal terrain clearance of 40 metres and 25 metre line spacing, the survey produced a high quality data set that was used as the basis for the interpretation of the geological features (Figure 2).

Encom Technologies Pty Ltd were commissioned to provide a comprehensive interpretation of the acquired datasets and provide information on interpreted anomalous features such as dykes, pipes, faults and joints that could influence future coal mining operations within the project area. Due to the subtle magnetic responses of target geological features specialised image enhancement and processing procedures were used to improve their resolution and hence, identification and geological classification.

Fig. 2 - Survey flight path – high density coverage

Approximately 120 features of interest were interpreted from the magnetic survey, including sills, pipes, dykes and joints. Although there are many features of interest, the majority of interpreted features have a low confidence rating, particularly in the joint classification where low magnetic anomaly amplitudes decrease the ability to reliably track the feature trend. High confidence features were targeted for further investigation.
Modelling of the intrusive sills, dykes and pipes was used to help understand the geological characteristics of the anomalies and assist with their identification and classification. The radiometric survey helped identify the major geological units, but did not directly detect the presence of subsurface igneous bodies.

The airborne survey was flown by a jet-ranger helicopter with the measurement equipment installed in a boom (stinger) in the front of the aircraft (Figure 3).

![Figure 3 - Aircraft used for low level survey operations](image)

The survey quality was very important for maximising the chances of detecting subtle magnetic anomalies from igneous intrusion. A gamma ray spectrometer was also included with the acquisition system to help with differentiation of geological units. The survey specifications and equipment of the airborne geophysical system flown by Fugro Airborne Surveys are shown in Tables 1 and 2.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey date</td>
<td>April to May 2005</td>
</tr>
<tr>
<td>Aircraft</td>
<td>Bell Jetranger 206B III</td>
</tr>
<tr>
<td>Flight line spacing</td>
<td>25 metres</td>
</tr>
<tr>
<td>Tie line spacing</td>
<td>250 metres</td>
</tr>
<tr>
<td>Traverse line direction</td>
<td>071 – 251 degrees</td>
</tr>
<tr>
<td>Tie line direction</td>
<td>161 – 341</td>
</tr>
<tr>
<td>Nominal terrain clearance</td>
<td>40 metres</td>
</tr>
</tbody>
</table>
ENHANCEMENT OF GEOPHYSICAL DATA

High-resolution aeromagnetic survey data represent a rich source of detailed information for mapping surface geology as well as for mapping deep tectonic structure. Traditional enhancement techniques, such as first vertical and horizontal derivatives (1VD, 1HD), analytic signal (AS), and high-pass in-line or grid filters are used in enhancing magnetic anomalies from near-surface geology. Two types of filters have been developed for the purpose of enhancing weak magnetic anomalies from near-surface sources while simultaneously enhancing low-amplitude, long-wavelength magnetic anomalies from deep-seated or regional sources. The Edge filter group highlights edges surrounding both shallow and deeper magnetic sources. The results are used to infer the location of the boundaries of magnetised lithologies. The Block filter group has the effect of transforming the data into “zones” which, similar to image classification systems, segregate anomalous zones into apparent lithological categories. Both filter groups change the textural character of a dataset and thereby facilitate interpretation of geological structures. (Shi and Butt 2004).

A suite of geo-filters were applied to the magnetic data set in an attempt to provide more contrast to geological features with subtle variations in magnetic response. Table 3 below lists the various enhancement techniques used and the target geological feature it is used to interpret. Figures 4 and 5 display the resulting enhanced images used in the interpretation.

<table>
<thead>
<tr>
<th>Enhancement Technique</th>
<th>Geological Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Analytic Signal</td>
<td>Intrusive pipes and major dykes</td>
</tr>
<tr>
<td>Edge Filter</td>
<td>Dykes and joint zones</td>
</tr>
<tr>
<td>First Vertical Derivative</td>
<td>Surface features, basement anomalies and sills</td>
</tr>
<tr>
<td>Tilt Filter</td>
<td>Subtle Geological boundaries</td>
</tr>
<tr>
<td>Area Filter</td>
<td>Cordeaux Crinanite, detrital material and sills</td>
</tr>
</tbody>
</table>

Table 2 - Survey Equipment

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Magnetometer</td>
<td>Geometrics G822A</td>
</tr>
<tr>
<td>Magnetometer installation</td>
<td>Stinger</td>
</tr>
<tr>
<td>Resolution</td>
<td>0.001 nanotesla</td>
</tr>
<tr>
<td>Sample rate</td>
<td>0.1 seconds</td>
</tr>
<tr>
<td>Sample separation</td>
<td>3.4 metres (average)</td>
</tr>
<tr>
<td>Spectrometer</td>
<td>Exploranium 256 channel GR820</td>
</tr>
<tr>
<td>Crystal volume</td>
<td>16 litres</td>
</tr>
<tr>
<td>Sample rate</td>
<td>1 second</td>
</tr>
<tr>
<td>Sample interval</td>
<td>34 metres (average)</td>
</tr>
<tr>
<td>Radar altimeter</td>
<td>Collins ALT50</td>
</tr>
<tr>
<td>Sample rate</td>
<td>0.1 seconds</td>
</tr>
<tr>
<td>Data acquisition system</td>
<td>Fugro DAS</td>
</tr>
<tr>
<td>GPS system</td>
<td>Fugro Omnistar 3000L DGPS receiver</td>
</tr>
<tr>
<td>Update rate</td>
<td>1 second</td>
</tr>
<tr>
<td>Navigation</td>
<td>Real-time differential GPS</td>
</tr>
<tr>
<td>Flight path recovery</td>
<td>Post flight differentially corrected GPS</td>
</tr>
</tbody>
</table>
Fig. 4 - Various enhancements of geophysical data
Fig. 5 - Various enhancements of geophysical data
REGIONAL RESIDUAL SEPARATION OF MAGNETIC DATA

This technique was specifically designed to enhance the magnetic response of intrusive sills that occur in the coal measures. A number of anomalous zones were identified by this technique and were interpreted to be caused by the presence of intrusive sills at depth.

To create this image the regional magnetic field variation due to basement rocks at depth (greater than 2000 m) is subtracted from the TMI grid to produce a residual image of magnetic intensity caused by near surface geology. The procedure used to produce a 3D model of the regional magnetic field is subjective and low confidence interpretations of magnetic sills within the coal measures were treated with caution.

The interpreted regional magnetic surface was produced by modelling and comparison with a subset of lines across the surveyed area. A number of spheres with variable magnetic susceptibilities were placed at a depth of approximately 6 km in a 3D model. Magnetic spheres at this depth produce broad magnetic anomalies, which are placed in various locations and depths in 3D space to emulate the approximate regional magnetic field. A regional magnetic surface is created from this model and subtracted from the surveyed TMI grid to produce a residual image of the resultant magnetic response, Figure 6.

Magnetic field variations due to changes in elevation were another correction that had to be incorporated into the sill modelling. Using the digital terrain model (DTM) the variations in magnetic field due to vertical displacement were subtracted from the flight line data used to model the sills. Figure 7 displays the regional residual separation image with the interpreted sills. The level of confidence of the sill interpretation was variable and correlations to borehole data are discussed later.
The interpretations provided by Encom incorporated some experimental combinations of gamma ray spectrometer and magnetic data in an attempt to produce a more definitive image of the surface geological boundaries.

These combinations were:

- RGB Image of Potassium (K), Thorium (TH) and Uranium (U)
- RGB Image of Potassium, Thorium and Uranium Ratios
- Merged Tilt Filter and RGB Radiometric Image

Images of these combinations are shown in Figures 8 to 10. From these enhancement techniques the boundaries of major geological units could be identified more accurately using the combination of their contrasting magnetic and radiometric signatures.

The resultant mapped boundary then could compared directly with the in-house geological model constructed by a combination of borehole data, seismic survey data and surface geological mapping of outcropping lithology. Any major differences in the datasets would indicate errors in the current model and anomalous features would require further investigation.
Fig. 8 - Combination K, U and Th

Fig. 9 - Combination K, U and tilt filter
Figure 11 displays the interpreted formation boundary interpreted from the data and modelled boundary constructed from a range of datasets by BHPB. The combined enhancement technique proved to be a useful tool in accurately mapping lithology outcrop in difficult and inaccessible terrain.
GEOPHYSICAL MODELLING

A range of geophysical models were constructed to simulate the magnetic signature of a number of prominent magnetic features identified on the enhanced magnetic data. The magnetic signatures that may be generated by dykes, pipes and sills of various orientations and depths were simulated to match the observed magnetic response in the data.

The following discussion outlines the models constructed to mirror the magnetic responses of potential dykes, pipes and sills that may be present in the Dendrobium area for a more definitive recognition of their resultant magnetic signature.

Dykes

There were a number of linear features that were identified on the magnetic datasets that were interpreted as possible dykes. These anomalies had variable characteristics along their length which suggested that they may be discontinuous. The ability to trace these features along reasonable strike lengths across rugged terrain suggests that the sources have moderate depth extent and are steeply dipping (Pratt and Foss, 2005)

Due to the nature of dyke bodies, being relatively thin and near vertical, the main influence on the magnetic signal detected is generated near the surface and it would be very difficult to determine if they extended to coal seam level.

In total six linear magnetic features were examined closely and models created in attempt to describe their possible thickness and orientation. The models were developed from alternate flight lines with 50m spacing and the anomalous signature modelled by the placement of vertical and sub-vertical magnetic bodies extending to depth under the flight paths. Figures 12 and 13 display a model constructed from the most prominent linear magnetic feature identified in the survey area.

Fig. 12 - Possible dyke modelled section on TMI and DEM images
The magnetic susceptibility values used in the modelling were exaggerated to enhance the predicted magnetic response of the various igneous bodies and to develop a recognizable magnetic signature for a range of orientations, thicknesses and depths.

![Fig. 13 - Perspective view of the modelled dyke reveals a general westward dipping body](image)

Results from the interpretation revealed a significant dyke or series of dykes that bisected the proposed mine plan in Dendrobium Area 3 in a west northwest direction. These dykes were suspected to be present in this area from previous investigations and projection from dykes intersected in earlier workings. From this data a more accurate approximation of their location was determined and drilling program designed to intersect these bodies and verify their existence. A brief case study of this project and successful results are discussed later.

**Igneous Pipes**

The pipes were modelled using a vertical/sub-vertical elliptic pipe magnetic body. The pipe anomalies are considered less reliable to model and interpret as they are not laterally extensive and are only intersected by a few flight lines. The anomalous expressions on each of the flight lines that intersect a relatively small vertical body vary across it giving it a recognizable bull’s eye signature.

There were a number of pipe features delineated during the interpretation but after further investigation the majority were attributed to cultural features such as steel borehole casing, drill rigs and other metalliferous man made objects.

One significant anomaly of interest was modelled to ascertain its nature and orientation. This feature was detected by a total of 12 flight lines which were modelled simultaneously using an elliptic pipe model, together with an additional negative anomaly immediately east of the pipe. This negative anomaly is associated with a gully and Wongawilli Creek. Figures 14 and 15 display the anomaly, eight central sections intersecting it and a perspective view of the model.
The pipe has been modelled to be 60 m in diameter with a magnetic susceptibility of 2 x 10^{-2} SI. The location of this feature is outside the current proposed mine plan and is yet to be investigated.
SILLS

A number of sill models were constructed in an attempt to identify the signal characteristics of a sill boundary. All models were constructed from the residual separation enhanced images (Figure 16).

The characteristics of magnetic anomalies over the margins of sills are dominated by the shape and abruptness with which the sill is terminated. If the sill has an abrupt termination (e.g. against a fault) then that margin is marked by a sharp magnetic anomaly which both maps the location of the sill edge and provides a means to estimate its depth. This edge anomaly is very similar in character to the anomaly you would observe if a dyke were placed at that location. If, however, the sill margin tapers then characteristics of the magnetic anomaly become less diagnostic and more problematic to interpret and model (Pratt and Foss, 2005).

Single flight lines were modelled a significant distance across the boundaries of proposed sills interpreted in the area. For the several sills interpreted different thickness, depth, boundary types and magnetic intensities were used to model the anomalous signatures obtained from the residual separation enhancement technique.

The magnetic susceptibilities of igneous sill in the modelling were exaggerated to define the changes of character of the signature for different scenarios in depth, thickness and geometry.

GEOLOGICAL INTERPRETATION AND TARGET INVESTIGATION CASE STUDY

Dyke Investigations

The interpreted geophysical dataset provided additional information supporting the presence of a series of suspected dykes that intersect coal seam formations within a proposed mine plan layout. A surface to inseam drilling program was designed to intersect vertical bodies that were thought to intrude the working section of the Wongawilli coal seam. Figure 17 displays a diagram of the surface to inseam steered drilling technique used to intersect inferred dykes that were interpreted in Dendrobium area 3.

Prior to the 2005 aeromagnetic survey the inferred dykes were projected from a combination of dykes intersect in mine workings, surface lineaments and a lower resolution aeromagnetic survey that was acquired in the 1989.
The analytical signal and edge filter enhancement techniques were used to improve the geophysical interpretations of the aeromagnetic data. Figure 18 displays images of the enhanced data sets and the associated interpretations of dyke anomalies. Please note the high magnetic readings associated with high voltage transmission lines that pass through the survey area. Using a combination of all datasets and taking into account access limitations optimum inseam drilling locations and borehole directions were designed to intersect the interpreted dykes.

In two of the inseam boreholes that were completed in this area dyke material was intersected at locations that correlate very closely to the interpreted dyke locations. Changes in penetration rate and measurement of gamma ray count while drilling aid in identifying the dykes when intersected. Nominally at these locations the drill stem is pulled back and a core sample taken of the intrusion to confirm its location and thickness. Figure 19 displays an aerial photo of the drill site locations with an overlay of the inseam drill holes (light yellow lines) with respect to the interpreted dyke locations (thick white lines). The points of intersection with the dyke are denoted by dark dots.
The results of this drilling program were very encouraging and the nature and orientation of the dykes can now be modelled more accurately. A number of conclusions can be made on the use of aeromagnetic methods and associated image enhancement techniques.

![Fig. 19 - Inseam drilling dyke intersections](image)

The drilling program has confirmed the presence of a number of dykes that would impact on Longwall mining operations and the following conclusions can be made on the geological nature of these intrusions.

- The dykes are not continuous along their linear trend,
- Are almost vertical in structure,
- Range in thickness from 1 to 10 m in thickness,
- They have high magnetic susceptibility.

**Correlations of known sill occurrences with interpreted features**

There are a numbers of igneous sills that exist in the Dendrobium area and the residual separation enhancement technique was investigated as a tool to map their lateral distribution at coal seam level. The difficulties in applying a unique geophysical method to image intrusive sills at depth are;

- In the mine lease areas, igneous sills have been deposited at different geological times and may vary greatly in composition, distribution, depth and thickness.
- Sill material with low magnetic susceptibility is difficult to differentiate from the host sedimentary sequences using magnetic geophysical techniques.
- The relatively small thickness of sills at depth with respect to the overburden thickness may not produce a strong enough source signal to be detected.
The geophysical properties of sills intersected by drilling in the area vary greatly in composition and associated physical properties. Table 4 below outlines the magnetic susceptibility and density variations found in a number of core samples that were intersected in the field.

Table 4 - Broad range of physical properties of sill material

<table>
<thead>
<tr>
<th>Core Sample</th>
<th>Magnetic Susceptibility (SI)</th>
<th>Density (g/cm3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cordeaux Crinanite</td>
<td>$899 \times 10^{-5}$</td>
<td>2.93</td>
</tr>
<tr>
<td>Nepheline Syenite</td>
<td>$58 \times 10^{-3}$</td>
<td>2.60</td>
</tr>
<tr>
<td>Nepheline Syenite (altered)</td>
<td>$22 \times 10^{-5}$</td>
<td>2.32</td>
</tr>
<tr>
<td>Dolerite</td>
<td>$600 \times 10^{-7}$</td>
<td>3.05</td>
</tr>
<tr>
<td>Dolerite (altered/weathered)</td>
<td>$25 \times 10^{-6}$</td>
<td>2.60</td>
</tr>
</tbody>
</table>

In total seven areas of sill were interpreted to occur in the Dendrobium Area. Some of the interpreted sills of high confidence correlated well with borehole data and those of low confidence did not. The results confirm that the imaging techniques for identifying possible areas of silling are limited and that igneous deposits with low magnetic susceptibility such as the Nepheline Syenite cannot be delineated using high resolution aeromagnetic techniques.

HIGH RESOLUTION AIRBORNE GRAVITY TECHNIQUES

Airborne gravity exploration techniques are used predominantly in regional geophysical exploration to delineate significant geological formations and structures in both the Petroleum and Mineral exploration industries. Once again, recent advances in technology have warranted assessment of this technique on targets with more subtle geophysical responses.

Airborne gravity gradiometer technology has been successfully used to explore for a range of ore types (IOCG, Iron Ore, Kimberlites) and for geological mapping. BHP Billiton has successfully demonstrated that the FALCON™ airborne gravity gradiometer (AGG) can be used over sedimentary basin environments, and has detected deep channels within them in a survey flown over the Gippsland basin. A survey in the Latrobe valley successfully delineated the coal horizons (Rose, 2005).

This method is based on the measurement of changes in the Earth's surface gravity due to the variations in the densities of subsurface geology. Gravity measurements are made using an airborne gravity gradiometer (AGG) system that was developed by BHP Billiton and Lockheed Martin.

In its simplest form, a gradiometer consists of two gravimeters. They experience the same aircraft accelerations (e.g. reference ellipsoid, latitude, Earth tide and isostatic effects). The gradient is simply the subtraction of one gravimeter response from the other, so most of these corrections cancel out, and we are only left with self-gradient and terrain corrections as the key factors (FALCON®, 2005).

A trial of this technology was considered as a mechanism to assist in delineating igneous intrusions at depth, specifically silling in the Dendrobium region as well as any major structural boundaries. To provide further information on the viability of this method, Falcon AGG were commissioned to demonstrate that the density contrast of igneous bodies at depth were sufficient to produce an anomalous signature.

Terrain effect

The terrain effect is an important correction that is applied to the Falcon data before an interpretation of the subsurface density variations can be undertaken. If the terrain effect is large as it is here, and it cannot be corrected adequately, then the errors introduced may be interpreted as having a different source. Terrain correction is applied with a constant density, chosen to be as close as possible to the outcrop. Reasons why the terrain correction may cause a problem include:

- The upper section being inhomogeneous, for example where incision of the topography exposes section with different densities
The Digital Elevation Model (DEM) is not sufficiently accurate

The Falcon AGG system has on board a laser scanner to measure detailed DEM. To get complete coverage, the line spacing should be 130m if flying at 80m above ground. Increasing the flying height enables the flight line spacing to be increased while still acquiring complete laser scanner coverage for the DEM.

Modelling of Geophysical Responses

Igneous intrusive deposits modelled from borehole data and mine intersections were used to model their synthetic gravity response, as they were a good representation of a range of possible sources. A synthetic survey was designed to cover the area of the Dendrobium mine and then processed as it would be in a Falcon survey.

A total of six possible sills were modelled at different depths from the surface and with different thicknesses to see if they could be imaged by their contrasting apparent density to the ambient host rock. The density values used in the modelling were between 2.9 and 3.0 g/cc which are typical of igneous bodies such as the Cordeaux Crinanite and various Dolerite deposits.

The synthetic modelling showed that with normal survey conditions and noise, the igneous intrusions are able to be measured with the Falcon AGG if they are 40 metres thick, and of sufficient aerial extent. Modelling was done in the absence of other density variations, including any related to the outcropping terrain and associated terrain corrections (Rose, 2005).

In reality the thickness of the majority of sills intersected in the area are around coal seam thickness (2 – 3 m), with the major bodies ranging from 10 to 50 m thick. Additionally the highly incised nature of the terrain in this area would result in difficult and dangerous flying conditions as well as extremely complex terrain corrections that would have to be applied to the data. The results indicate that the igneous bodies would have to be of significant thickness and distribution to have a detectable response and although results are encouraging, the difficulty in directly imaging the distribution of intrusive sills in this area would be highly experimental.

CONCLUSIONS

Airborne geophysical techniques have been found to be effective in delineating surface and subsurface features and, when used in conjunction with other exploration techniques, become an important tool for developing a comprehensive geological model.

Integration of various airborne geophysical datasets is essential for successful interpretations of subtle geophysical responses. With the aid of more advanced processing, mathematical enhancement techniques and higher confidence in geophysical data, a more accurate exploration campaign can be designed to verify the presence of specific geological targets.

These techniques have been successfully used by Illawarra Coal to obtain a more detailed geological understanding of igneous intrusions and the nature of geological structures. This, in addition to and when used in conjunction with other exploration data-sets, provides an invaluable tool to assist in the development of effective mine plans.

REFERENCES


