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Interpretation Report

Rosebery High Resolution 3D Seismic Survey

Rosebery, Tasmania

For

Minerals and Metals Group Limited.

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Executive Summary

An interpretation of high resolution three-dimensional (3D) seismic reflection data collected by HiSeis at the Rosebery minesite was conducted in order to achieve a number of objectives. These were namely:

1. Determine whether the seismic method was successful in imaging geology known to exist in the area.
2. Observe whether the mineralization was being directly detected by seismic in the form of amplitude anomalies.
3. Decide whether seismic was successfully imaging target geology further down dip.

Paradigm's GOCAD was the primary software employed for the integration of a number of geophysical and geological datasets. Upon interrogating the seismic it was found that the 3DPSTM AGC cube was best suited to carrying a structural interpretation of the subsurface geology in conjunction with the instantaneous phase attribute. Utilising these two datasets allowed for the interpretation of what appears to be the Rosebery and Mount Black Faults, which were identified based on the intersection and truncation of reflector geometries.

An amplitude-consistent cube was also utilized for the purpose of direct detection of mineralization. Based on physical rock property measurements it is expected that mineralization would provide one of the largest acoustic impedance contrasts in the area, which should result in anomalously high amplitude values at these interfaces. Based on this, amplitude iso-shells were created using cut-offs that highlighted a correlation between a high amplitude seismic reflector with the z lens mineralization within the prospective zone. Based on these iso-shells, a new potential target was identified further down plunge of the controlling structures.

Limitations in the effectiveness of the seismic brought about by the position of the prospective area sitting in the bottom corner of the seismic cube affect the quality of a definitive interpretation. However, the interpretation exercises carried out and their apparent correlation with known structures show that seismic appears to be imaging the key geology in the area and has the potential to be used as a viable exploration technique.

A number of recommendations are made to improve future interpretation work on data acquired from the Rosebery minesite:

- Careful design of future surveys allowing for the maximum chance to achieve the objectives of the survey
- Utilising the 3DPSTM AGC processing for structural interpretation while using the amplitude-consistent processing for amplitude anomaly identification
- Integrating results from subsequent drilling or geophysics

Contents

Introduction

This document contains 6 primary sections. An Executive Summary as seen above, this Introduction, a Software overview, a Dataset overview, Interpretation overview followed by Conclusions and Recommendations. Each section aims to define the processes involved in the interpretation phase of the Rosebery 3D seismic dataset.

The objectives of the interpretation were three fold:

4. Determine whether the seismic method was successful in imaging geology known to exist in the area.
5. Observe whether the mineralization was being directly detected by seismic in the form of amplitude anomalies.
6. Decide whether seismic was successfully imaging target geology further down dip.

Software

Interpretation of the Rosebery 3D seismic data set included the use of Paradigm's GOCAD Mining Suite for data display, dataset integration, the creation of 3D volume surfaces and structural interpretation. All outputs were saved in a Gocad project at the end of the interpretation session.

GOCAD Mining Suite

GOCAD Mining Suite was the primary interpretation software utilized. It offers the ability to integrate multiple geophysical and geologic datasets such as seismic cubes, electromagnetic data, satellite images, borehole information and previously interpreted surfaces and 3D volumes (*Figure 1*). This data is displayed in a user-defined coordinate system and provides the ability to slice through data in all orientations: in-line, cross-line, depth slices and arbitrary slices. Visually GOCAD allows variation and customization of amplitude colour spectrums and the ability to assign transparency to ranges of data, facilitating the display of multiple datasets at the same time.

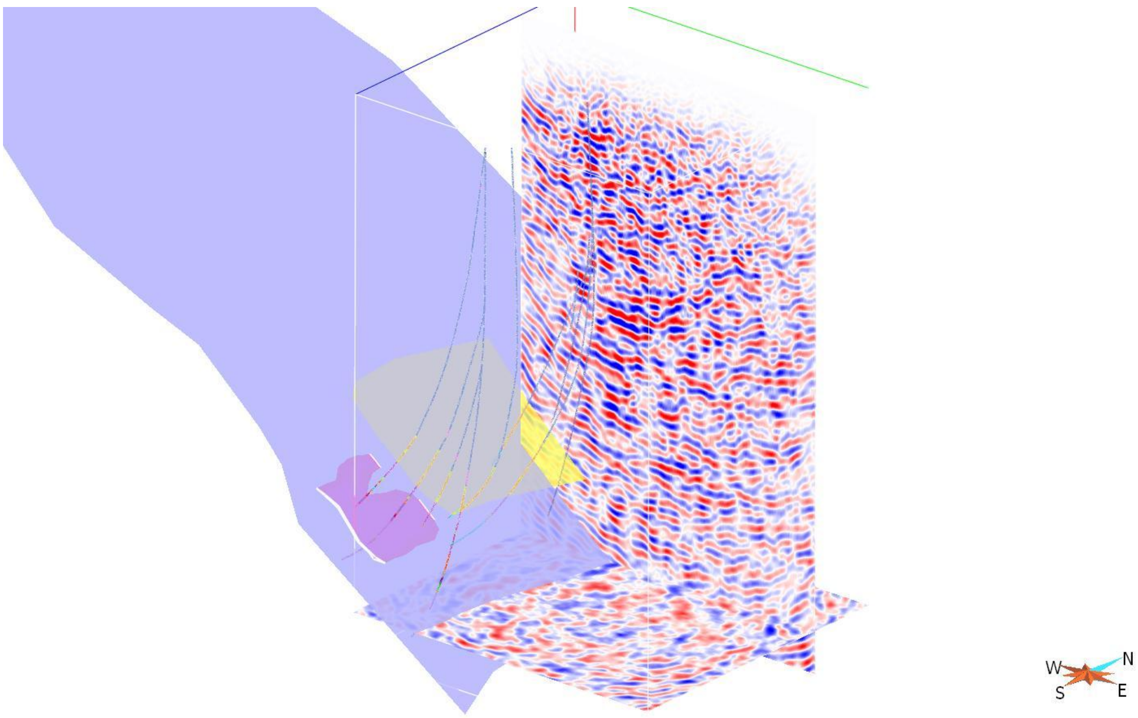

Figure 1: GOCAD 3D viewer with multiple datasets displayed.

Datasets

Coordinate System

The interpretation process involved the comparison and amalgamation of a number of datasets. These include geophysical, geological and borehole data. The interpretation was carried out in local mine coordinates but the seismic was acquired in GDA94. In order to perform the coordinate transformation in Gocad two reference points must be known in both coordinate systems. In the case of the Rosebery seismic data this is:

	GDA94			Local Mine Grid		
Name	Easting	Northing	elev	Easting	Northing	elev
ref 1	379391.3	5378631	0	1235.9	4102.336	3050
ref 2	379595.5	5377550	0	1224.3	3002	3050

An additional translation in the z-direction of +600 m was used to bring the seismic cubes to the seismic reference datum.

Seismic Datasets

A number of seismic datasets were provided to aid in the geologic interpretation of the data. These consisted of the primary *seismic amplitude cube* as well as a number of attributes generated from this.

Seismic Amplitude Cube

The seismic amplitude cube is generally used as the fundamental cube for carrying out a seismic interpretation. The seismic amplitude represents the contrast in acoustic impedance across geological interfaces and is therefore used to indicate lithology type at this position. Although many other factors influence the seismic response, the integration of more datasets and more information help to constrain the response and reduce the uncertainty.

In the case of the Rosebery dataset both a high resolution Automatic Gain Control (AGC) 3D Pre-Stack Time Migration (PSTM) cube was provided as well as a lower frequency amplitude-consistent (AC) 3DPSTM cube. The AGC cube utilises a harsh amplitude balancing tool that brings out subtle structures at the cost of reducing relative amplitude differences between seismic events. The AC cube works opposite to this in that it is processed to maintain relative amplitude differences between seismic events at the cost of resolution.

Initial processing also produced a Migration After Stack (MAS) cube that after comparison with the 3DPSTM cubes was deemed insufficient in terms of data quality for further use.

Cosine Perigram

Cosine perigram is the product of instantaneous amplitude and the coherency (similarity) coefficient multiplied by the cosine of phase. This attribute emphasizes the lateral continuity of strong events and is extremely useful in identifying structural features.

Instantaneous Phase

A derivative of the complex trace, instantaneous phase is used to enhance the lateral continuity of reflectors, especially in noisy areas. This attribute is particularly useful for aiding in horizon interpretation and observing the geometrical relationship between reflectors.

Geologic Datasets

Models

A number of geologic surfaces were provided by MMG geologists that represented previously interpreted structures from drillhole core logging. These included the key Rosebery (RF) and Mount Black Faults (MBF), which are believed to constrain the prospective zone of mineralization containing the Z lens mineralization. Other interesting features identified in core were also modeled and provided to observe whether they were correlatable with the seismic.

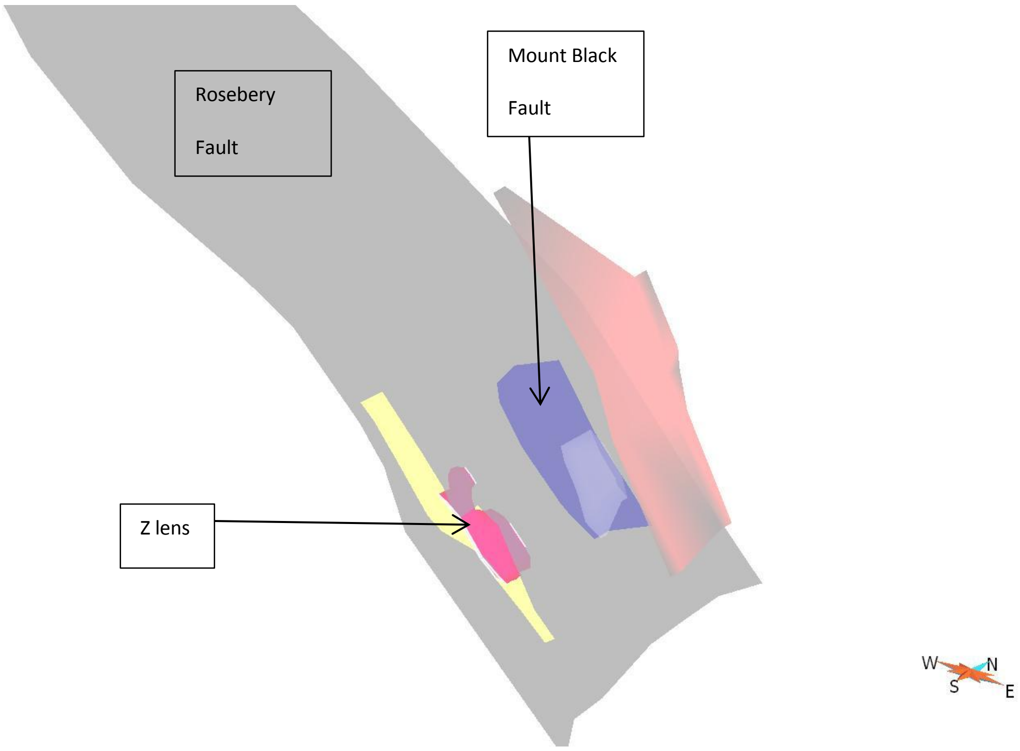

Figure 2: Geologic models in 3D space. Primary structures highlighted.

Boreholes

A drillhole database from the survey area was also provided by MMG (*Figure 3*). A number of these drillholes contained lithological zones interpreted from core, which are represented as coloured zones along the drillhole path. Assay data was also provided for these holes, which indicated the location of mineralization intercepts. This gave a reliable glimpse into the subsurface geology and was considered ground truth for the interpretation of the seismic data.

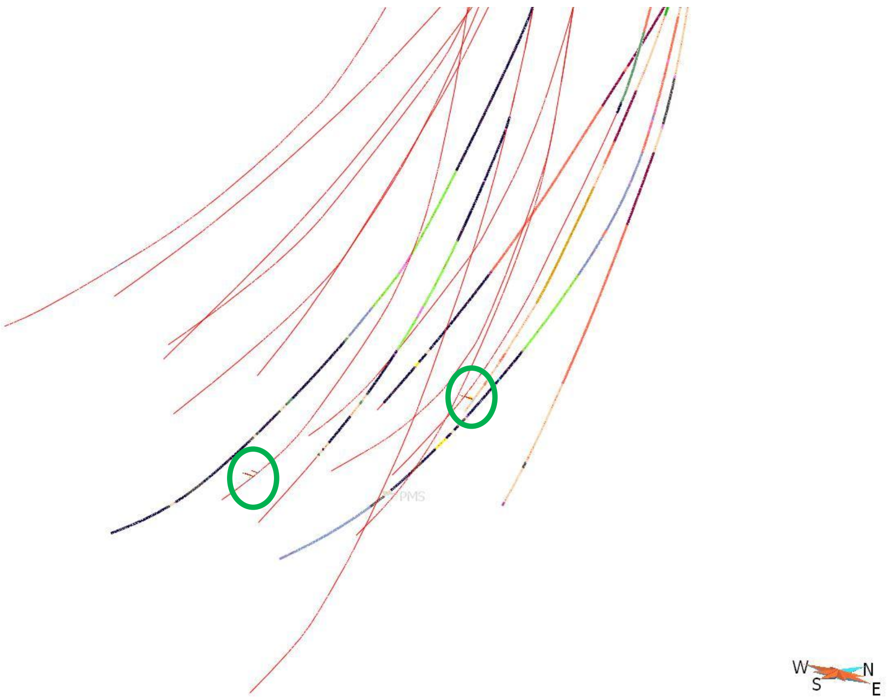

Figure 3: Drillholes coloured by stratigraphy with lead-zinc assay spikes circled.

Interpretation

A collaborative interpretation session was conducted over three days in the HiSeis office, Perth, Western Australia, beginning Wednesday 10th October, 2012. Geophysicists and geologists from both MMG and HiSeis spent 3 days interrogating the data with the objective of achieving a number of major outcomes. These were:

1. To determine whether the seismic method was successful in imaging geology known to exist in the area.
2. Observe whether the mineralization was being directly detected by seismic in the form of amplitude anomalies.
3. Decide whether seismic was successfully imaging target geology further down dip.

At the beginning of the session only the MAS cube was available for scrutiny. Unfortunately this was the lowest quality output and was found to be somewhat limited in what value it was able to add to the interpretation. Initial collaborative efforts were spent scrutinizing the MAS cube relative to subsurface information provided by MMG geologists in the form of drillholes and geological surfaces based on drill core interpretations.

Due to the inherent limitations in the post-stack migration algorithm, coupled with ambiguity in the z-direction of the cube due to a lack of velocity control to constrain the time-depth conversion it was difficult to carry out a credible analysis of whether the seismic method was successful in imaging the subsurface geology. It was at this stage that a 3D Pre-Stack Time Migration (PSTM) was decided to be run but due to the computer intensive nature of the algorithm preliminary results of a desampled cube were only made available towards the end of the interpretation session. Although promising, there was no time to conduct an in-depth analysis of how well the cube managed to image the subsurface geology.

At the conclusion of the collaborative interpretation session HiSeis saw the need to attempt further processing streams beginning with re-running the 3DPSTM at 2 ms followed by running an amplitude-consistent processing flow.

The results of further processing made it clear that the 3DPSTM AGC cube would be best suited to carrying out a structural interpretation in the area in conjunction with the attributes generated from the AGC cube. This is due to the higher resolution provided by this particular processing stream and the improved imaging of subtle structures through the amplitude gain applied. For the case of Rosebery, the most useful attribute was found to be the instantaneous phase as it highlighted geometric relationships between the reflectors. These could be used to infer the presence of faults, such as the MBF and the RF.

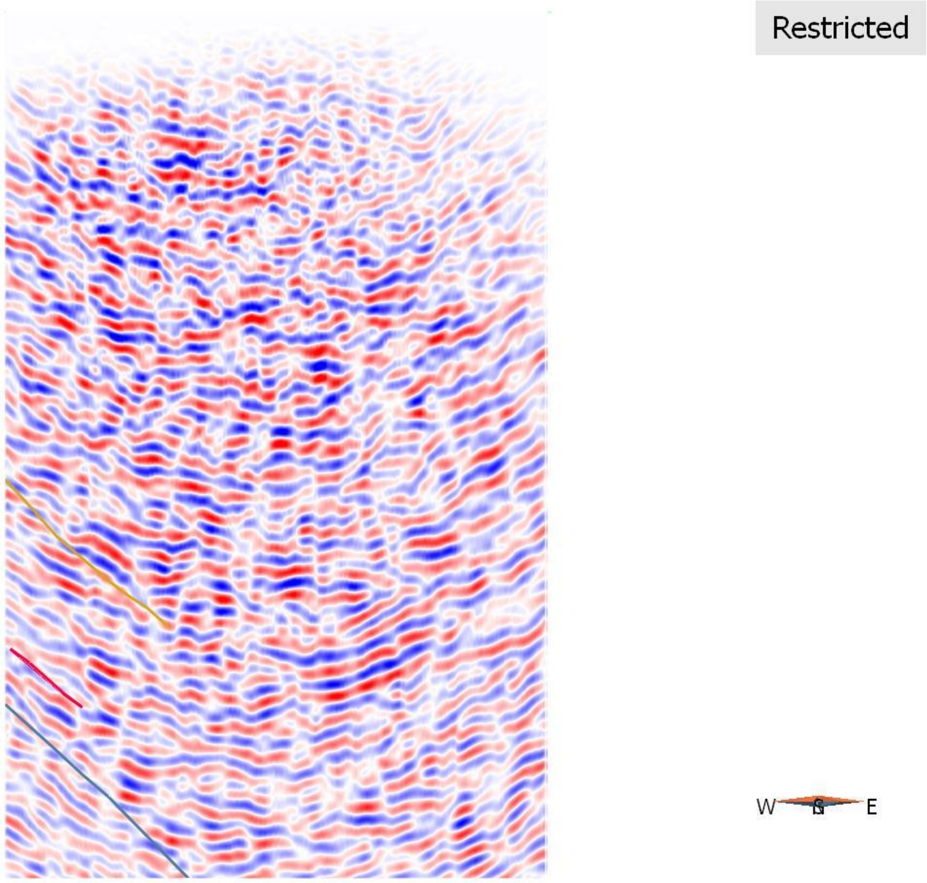

Figure 4: 3DPSTM AGC section with the Mount Black Fault in yellow, mineralisation surface in red and the Rosebery fault in blue.

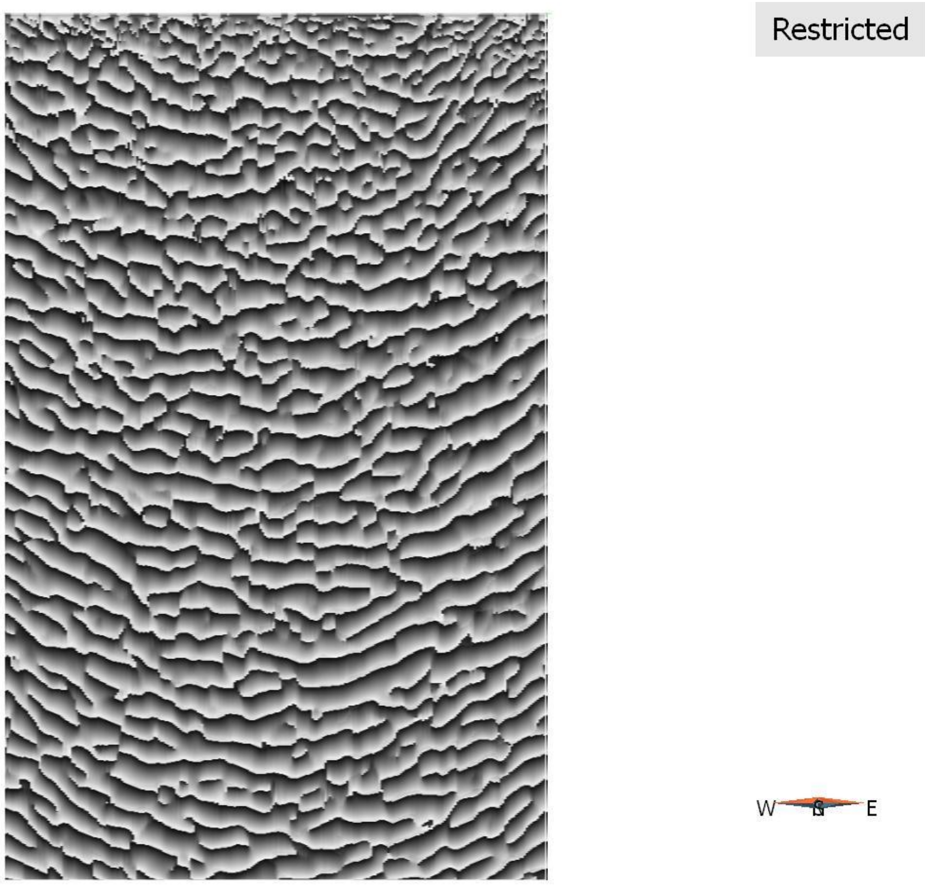

Figure 5: 3DPSTM AGC instantaneous phase.

Significant caveats are attached to the seismic data and should be made clear prior to an interpretation. Firstly, the prospective area occupies a region of the cube highly contaminated with processing artifacts. The bottom corner bounded by the RF and MBF is in a low fold portion of the cube (*Figure 6*) that contains migration artifacts known as ‘smiles’. When looking at a section, such as *Figure 4*, it can be seen that the edges of the section tend to pull up into what are commonly referred to as ‘smiles’. These are a consequence of the migration algorithm and not geologically related. However, in the case of Rosebery the target structures tend to dip in a similar orientation to these smiles. This makes interpretation of actual geological events more difficult and increases the reliance on geometrical relationships, such as those highlighted in the instantaneous phase cube, as well as auxiliary datasets such as the modelled surfaces based on drillhole intersections.

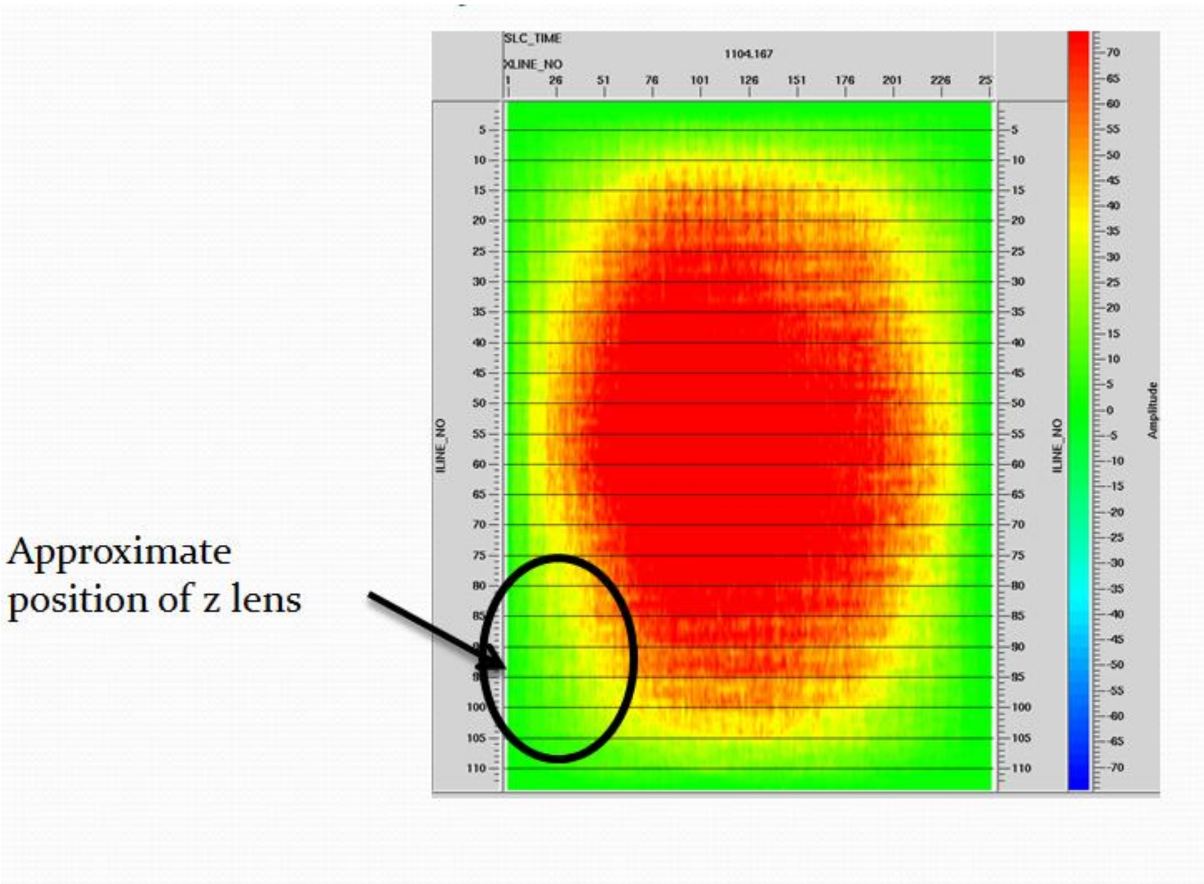

Figure 6: Fold map at approximate depth of interest (1100 m).

Based on physical rock property measurements it was established that the mineralisation was expected to provide a substantial acoustic impedance contrast with surrounding rock. This indicated the potential for mineralisation targeting via the identification of amplitude anomalies. To facilitate this an amplitude-consistent processing stream was carried out. The algorithms utilised in this stream aim to maintain relative amplitude differences between seismic events and therefore preserve strong amplitude responses brought about by variation in physical properties. From this strong amplitude responses observed in the AC cube could reliably be related to strong physical property contrasts, such as those expected to result from mineralisation. To aid in the identification of amplitude anomalies iso-shells were created in Gocad using an arbitrary amplitude value cut-off. This cut-off was based on what highlighted the known mineralisation best and then looking for similar amplitude signatures throughout the prospective area. Based on this technique, a new target was identified in the AC cube highlighted in *Figure 7*.

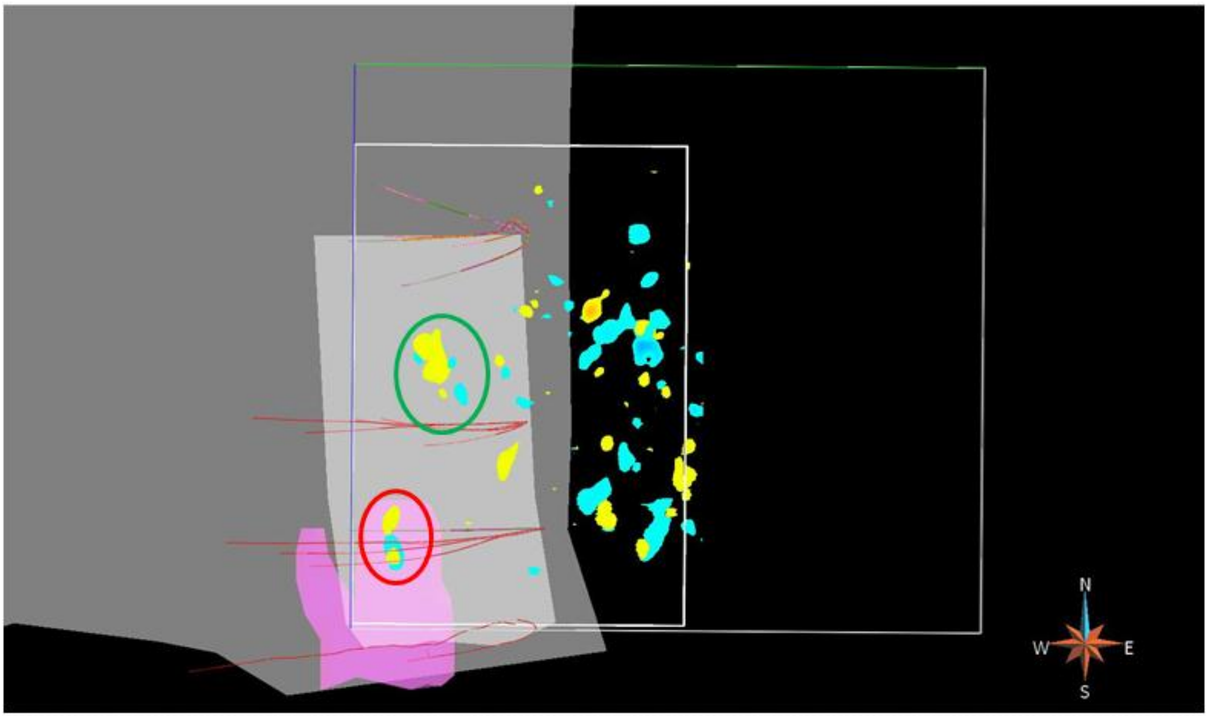

Figure 7: Iso-shells created from the AC processed cube. Z lens is circled in red and a potential down plunge target is circled in green.

HiSeis conducted an independent interpretation of the key surfaces (RF & MBF) using the 3DPSTM AGC and associated attribute cubes. The primary criteria for the identification of these faults were the geometric relationships of reflectors (*Figure 8*) and their intersections/truncations, which were particularly highlighted in the instantaneous phase attribute cube. This criteria was found to be particularly successful in picking out major fault structures, that correlated extremely well with modelled surfaces based on drillhole intersections.

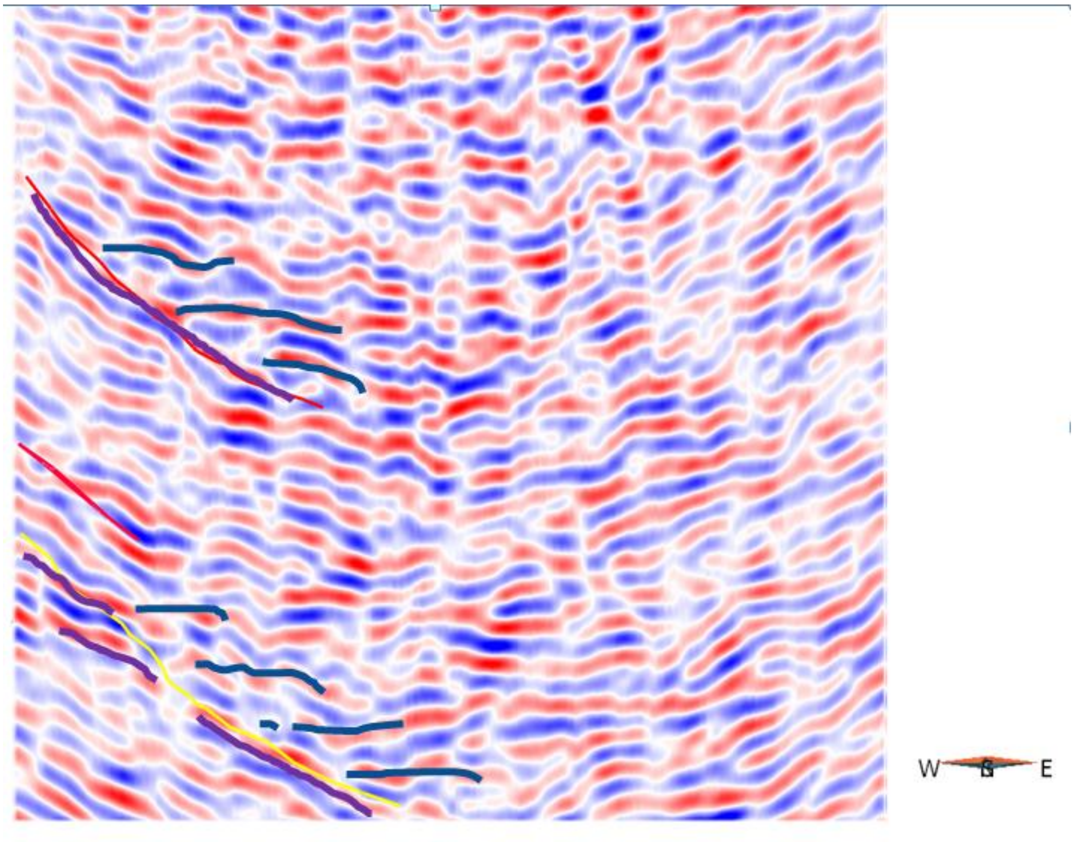

Figure 8: 3DPSTM AGC section highlighting the geometric relationship of reflectors.

Conclusions and Recommendations for Future Interpretations

An initial interpretation of the Rosebery 3D seismic data was conducted during an office visit by MMG personnel to the HiSeis office during the week beginning Wednesday 10th October, 2012. A subsequent interpretation conducted by HiSeis identified a number of fault surfaces, as well as a potential new down-plunge target. Due to the high complexity of the geology encountered and the limitations associated with the survey design identification of the key structures was difficult to carry out. However, reflector geometries provided an indication of potential structures that lined up well with surfaces modeled from drillhole intersections. Also, using the amplitude-consistent processed cube showed the correlation of a high amplitude event with the z lens mineralization. Based on this, a new potential target was also identified further down plunge. Therefore, it is believed that seismic is imaging the key geologic structures in the area and the potential for seismic as an exploration technique bears credence at the Rosebery minesite. A number of recommendations are made to improve further interpretations in the future:

- Careful design of future surveys allowing for the maximum chance to achieve the objectives of the survey
- Utilising the 3DPSTM AGC processing for structural interpretation while using the amplitude-consistent processing for amplitude anomaly identification
- Integrating results from subsequent drilling or geophysics