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Seismic Exploration for Volcanogenic Massive Sulphides - The Rosebery Zinc, Lead, Copper Mine, Tasmania

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SUMMARY

An experimental 3D seismic survey conducted in extreme topographic and weather conditions in Rosebery, Tasmania, Australia - a known VMS province - was aimed at validating the technique for this region as well as prospecting further down dip for additional mineralisation. Significant challenges were faced during the survey design stage stemming from trying to image dipping structures while taking into account extreme topographical variation of up to 400 m using a limited survey grid of approximately 1.5 km². Initial processing results were less than satisfactory with the majority of the target geology being migrated outside of the conventional 3D space. By expanding the geometry additional space for migration was provided, allowing seismic events to migrate to their true spatial position. This unambiguously imaged the controlling structures and achieved the major objectives of the trial survey.

Introduction

The Rosebery mine of northwest Tasmania has been in continuous operation since 1936 (MMG Limited, 2013). Consisting of a polymetallic base metal VMS deposit, the most recent additions to the resource have been down plunge and at depths of greater than 1.5 km. Coupled with this, pyrrhotite-pyrite mineralised black shales render downhole electromagnetic techniques ineffective. Hence, there is a need for a new exploration tool capable of imaging geology at depth. Surface seismic reflection was trialled at Rosebery to determine whether it was capable of imaging the structures that controlled mineralisation and potentially the mineralisation itself. This paper discusses the outcomes of this trial and a number of significant issues encountered during the design, acquisition and processing of this dataset.

A petrophysical study was conducted to determine whether sufficient acoustic impedance contrasts existed between the massive sulphides and host rocks. Although the p-wave velocities were generally lower than the surrounding units, a density contrast that was mostly double that of the other units produced acoustic impedance contrasts that should result in strong reflections from the massive sulphide contacts.

Data Acquisition and processing

The initial survey was designed to meet two objectives: The first was to image the controlling structures at depth and if possible the known orebodies to validate the seismic technique in the area and the second was to prospect down-dip for further mineralisation. The design process was extremely difficult due to dipping structures (approximately 45 degrees), large topographical variation on mountainous terrain (400 m variation) and limited survey extent (approximately 1.5 km²) owing to budget constraints.

The Rosebery survey was conducted in an area of extreme topography and vegetation that was only accessible by foot. With the lack of vehicle access, explosives buried to a depth of approximately 2 m was chosen as the source type. However, the variability of the near-surface cover meant that source coupling changed from excellent when coupled to fresh rock to very poor when the fresh rock was deeper. On top of this, intermittent rain affected raw data quality, contaminating the shot gathers with high amplitude random noise spikes.

Rain drop noise contamination prevented the application of true amplitude recovery techniques. Instead, robust amplitude scaling (AGC) was used during the processing to reduce high amplitude noise spikes and prevent artefacts contaminating the volume during later processing stages. The area of interest occupied the lower corner of the volume, severely limiting the ability of the migration algorithm to migrate the energy to their true spatial position. Therefore, initial attempts at migration suffered considerably from poor fold, offset and azimuthal distribution and accordingly low signal to noise (S/N) ratio. Post-stack migration was far from satisfactory, with Pre-Stack Kirchhoff Time Migration (PSTM) handling the data slightly better. Controlling structures were initially interpreted using the geometrical relationship of reflectors and their truncations against more prominent reflectors as the structures were not clearly expressed in the data.

After exhaustive trace killing of raw data affected by noise spikes Preserved Relative Amplitude (PRA) processing was attempted in a bid to highlight the strong reflections expected from the known massive sulphide lens. It was found that the highest amplitude events within the prospective area correlated with the location of a massive sulphide drillhole intercept. Not only that, but another amplitude anomaly existed further down strike that remained untested. Therefore, it was believed this particular stream of processing managed to directly image known and potentially new mineralisation.

PSTM of the 'Expanded data cube'

Finally, an attempt to expand the binning grid was made to provide additional space for migration. This was based on the target geology occupying the bottom corner of the conventionally binned grid. Numerical modelling confirmed that migration was moving the majority of the seismic energy outside of the conventionally binned volume. Manual intervention to increase the number of grid cells in all

directions led to an original cube of dimensions 1.26 km x 1.13 km being expanded to 3.2 km x 3.1 km. This resulted in a greatly improved seismic volume that unambiguously imaged the target structures. PSTM performed on the conventional and expanded cube are shown in Figure 1.

The expanded PSTM clearly imaged two high amplitude and coherent reflectors quite a distance away from the edge of the conventionally binned grid (Figure 1). This demonstrates that overriding the default parameters during geometry definition should be taken into consideration in order to be able to image reflectors outside of the formal grid boundaries. This is of a particular importance for hard rock seismic exploration where a 3D survey grid is often restricted in size due to environmental issues and budgeting constraints. Theoretically, with three seconds of recording time and velocities averaging 6 km/sec, we could obtain reflections from steeply dipping structures up to 9 km around the nominal acquisition grid. Such images could be distorted but may yield very important geological information. For little extra effort the expanded cube PSTM is likely to provide additional information that could be important for exploration.

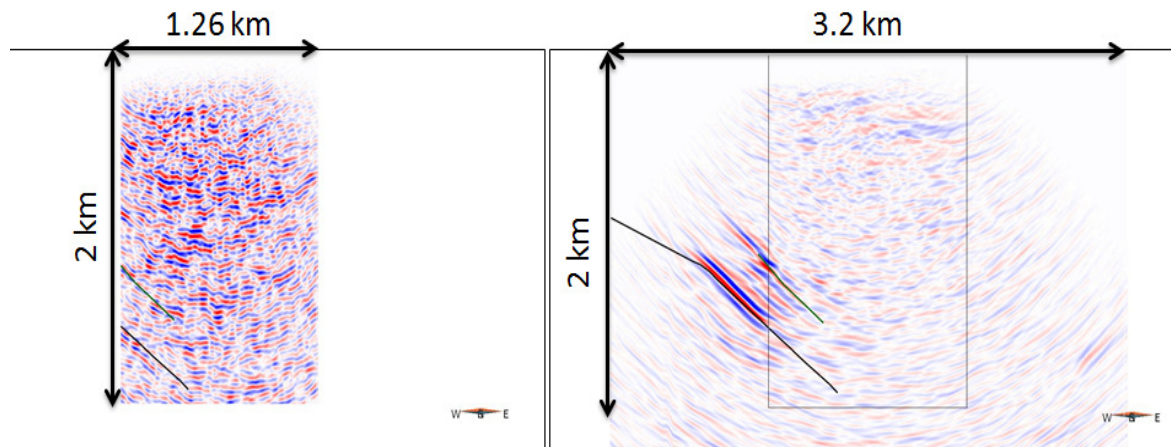


Figure 1 Conventional geometry PSTM cube (left) and expanded geometry PSTM cube (right). Controlling structures based on drilling outlined in black and green.

Conclusions

An experimental 3D seismic survey conducted in extreme topographic and weather conditions over a known VMS province was aimed at validating the technique for this region as well as prospecting further down dip for additional mineralisation. Significant challenges were faced during the survey design stage stemming from trying to image dipping structures while taking into account extreme topographical variation of up to 400 m using a limited survey grid of approximately 1.5 km². Initial processing results were less than satisfactory with the majority of the target geology being migrated outside of the conventional 3D space. By expanding the geometry additional space for migration was provided, allowing seismic events to migrate to their true spatial position. This unambiguously imaged the controlling structures and achieved the major objectives of the trial survey.

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References

MMG Limited [2013] Rosebery Fact Sheet, <http://www.mmg.com/en/Investors-and-Media/Reports-and-Presentations>.