Offering new geological insights to the Mawson Ni-Cu-Co prospect via seismic data reprocessing

Alan Meulenbroek
Velseis Pty Ltd
alanm@velseis.com

Mario Vecchi
retired
mvecchi@velseis.com

SUMMARY

Velseis recently completed the re-processing of the Mawson 3D seismic survey for Legend Mining Limited (Legend). Feedback from Legend has indicated that the re-processing offers an improved visualisation and representation of Legend's geological models and understanding for Mawson based on hard data points from diamond and reverse-circulation drilling.

The main differences between the re-processed data and the legacy data are the presence of the base-of-cover event in the re-processing, the break in the Mawson Fault and fewer migration artefacts. Each of these differences to the legacy processing has given new insights into the structures daylighting at the base-of-cover as well as deeper project-scale structures which provide context to conceptualising a geological history of the Mawson Prospect. There is confirmation that the re-processed data better supports Legend's geological model and the inferred geological history compared to the legacy processing.

More broadly, this case-study illustrates that with careful data processing, the seismic method can be employed in this context to add value to products traditionally used in minerals exploration.

Key words: Legend Mining, Mawson, hard-rock seismic, minerals, geological interpretation.

INTRODUCTION

The seismic method has traditionally been used in sedimentary/soft rock environments (e.g coal, oil and gas) where relatively large changes in acoustic impedance, Z (product of seismic velocity, V and density, ρ), produce high reflectivity at the target interface. Following appropriate data processing, this can result in high quality imaging of subsurface targets and associated structural features.

Minerals companies are increasingly turning to the seismic method to produce products which can complement more traditional sources of geophysical information (e.g. potential fields) for the purposes of developing a more complete geological interpretation in a cost-effective manner. There are, however, challenges with applying the seismic method in these environments. For minerals targets, seismic velocities can be much more uniform throughout the volume, meaning any observed reflectivity will predominantly arise from differences in rock density only. This can result in lower reflectivity overall compared to a sedimentary environment.

In a coal environment, the reflectivity is directly caused by the interface between the target coal seams and the surrounding host-rock. In the minerals environment, the target ore body may not be reflective at all. However, reflections can occur at interfaces between other geological or structural features which can provide context for geological interpretation and modelling of the target ore-body.

The challenges in applying the seismic method to the minerals environment require careful consideration of parameter choice for both survey design and subsequent data processing. This paper details a minerals seismic case-study from Western Australia where the client requested re-processing external to the original acquisition and processing company.

GEOLOGICAL CONTEXT AND 3D SURVEY

The Mawson 3D seismic survey, located in the Rockford project, Fraser Range, Western Australia, was acquired for Legend Mining Limited in November and December 2021. The prospect hosts mafic-ultramafic intrusion/s within a folded metasedimentary assemblage. Exploration at the Mawson prospect is primarily focussed on magmatic nickel-copper-cobalt (Ni-Cu-Co) (Figure 1).

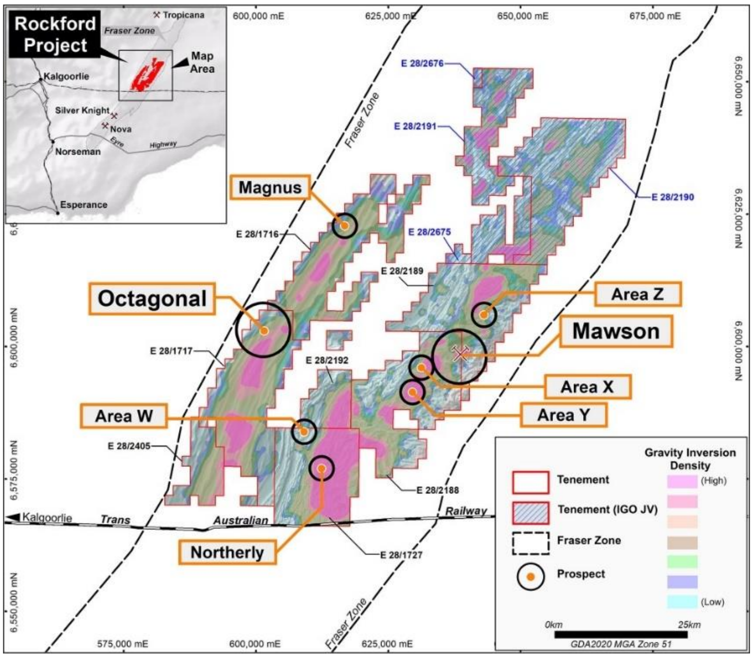

Figure 1. Location and geological context of the Mawson 3D seismic survey within the Rockford Project, WA. (legendmining.com.au/projects/fraser-range-rockford/)

The data were acquired using a 60,000lb Vibroseis source, 20 second sweep, frequency range of either 6-120Hz or 6-160Hz depending on the location within the survey. Figure 2 shows the source (red) and receiver (blue) locations. A total of 6012 shots were recorded into 8300 receivers which were all live for every shot. Receiver group interval was 12m/18m and source interval was 12.5m. Sample rate was 2ms.

The main objective of the survey was to aid in the understanding of Mawson's geological history such as structural, timing, and deformation events as well as identifying the seismic response of the host intrusion.

The 3D data were originally processed by the acquisition company. Following this, Velseis was contracted to re-process the data with the aim of providing an alternative product to the original processing.

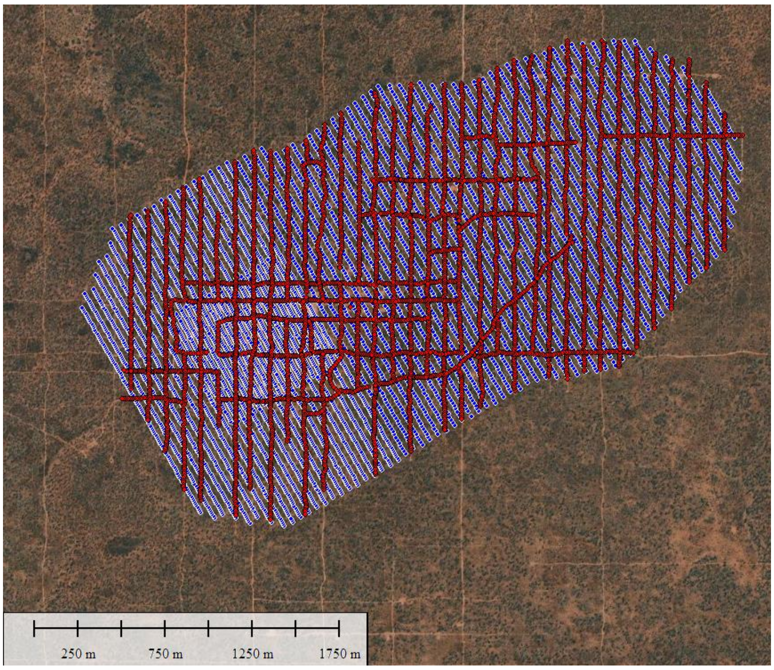

Figure 2. Mawson 3D survey. Receivers are shown in blue and sources shown in red.

DATA-PROCESSING

Re-processing of the data followed broadly similar flows to the original processing (statics, multiple rounds of velocity picking and residual statics, noise attenuation, deconvolution, PSTM, PSDM). Parameters at each processing step were tested and quality controlled to ensure no reduction in data quality at each step.

Figure 3 shows a representative shot gather ordered by absolute value of offset. Note the relatively poor signal to noise which can be typical of minerals seismic datasets (compared to seismic data from sedimentary basins). The velocity of the refractor (top red line) is measured at approximately 5200m/s. This refractor velocity varies across the survey. Projecting this refractor back to zero-offset yields an intercept-time of ~180ms which indicates a deep weathering profile.

The strong coherent noise (bottom red line) was attributed to ground-roll, although there were areas of faster coherent noise visible. Also visible in the mid-far offsets are regions of surface-noise, possibly caused by vehicles moving during recording. These sources of coherent noise were attenuated in the cross-spread domain in re-processing.

After PSTM, Kirchoff PSDM was used to provide further imaging improvements. The near-surface (weathering) portion of the initial velocity model was developed using multiple constant-velocity PSDMs and laterally interpolating. Below this, a constant velocity of 6000m/s was used. This value was chosen based on analysis of interval velocities in different parts of the survey. A gradient was applied to the velocity boundary between the weathering and sub-weathering layer to remove sharp velocity boundaries which Kirchoff migration does not handle well (Schulte, 2012). To ensure consistency between the velocity model and the input seismic data, the long-wavelength statics were removed from the seismic data prior to PSDM.

A velocity model was developed iteratively via reflection tomography. In general, it is better to introduce small changes gradually, rather than large changes all at once. In this context, the velocity updated was restricted to +/- 10% at each iteration. The optimum image was derived after 4 velocity update iterations. Due to the large changes in velocity across the base of cover interface and the vertical smoothness of the velocity model, the depths of seismic events may not be precise when compared to the drillhole data. These data were therefore calibrated to modelled fault-planes which were derived from drillhole data observations.

The results and discussion to follow are based on the calibrated PSDM volume.

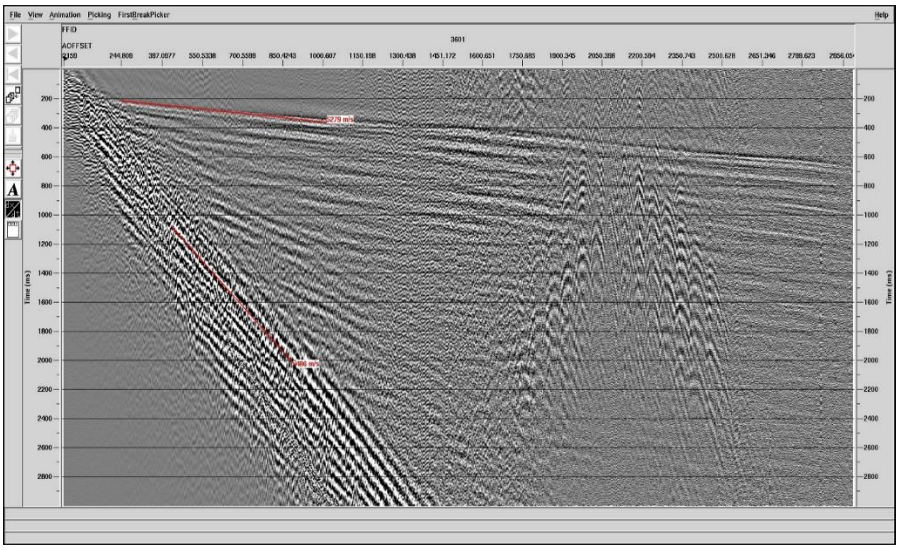

Figure 3. Typical shot record ordered by offset. The velocity of the red lines representing the refracted energy is ~5279m/s and the coherent energy ~486m/s.

RESULTS AND DISCUSSION

Figure 4 (legacy processing) and Figure 5 (re-processing) show the same single inline from each respective seismic volume. Crosslines are shown in Figure 7 (legacy processing) and Figure 8 (re-processing). Figure 6 and Figure 9 show the same inline and crossline from the re-processed dataset with the current intrusion model overlay supplied by Legend Mining. The green volume represents the magmatic chonolith (irregular igneous intrusion) inside of which are the primitive ultramafic cores which represent outwards concentric fractionation (red, purple and blue). Legend Mining's 2023 Maiden Ni-Cu-Co Mineral Resource is hosted within ultramafic assemblages like those seen in Figures 6 and Figures 9 (Legend Mining, 2023)

There are several key differences between the legacy and re-processed PSDM versions which have implications for geological interpretation and hence resource estimation:

- The absence of the shallow horizontal event in the legacy processing,
- The discontinuity in the dipping reflector (Mawson Fault) in the re-processed version,
- Presence/absence of migration artefacts.

One of the biggest challenges Legend faces in exploring in the Fraser Range is the almost total lack of outcrop. The deep cover makes field mapping impossible. Without this ability to conduct geologic field mapping such as structural measurements and lithological contacts, models are purely based on drillhole intercepts and sometimes predicting structure between sparse drillhole intercepts can be problematic. This is where the seismic method can be used to image hard-rock structure in a cost-effective manner and fill in the gaps between sparse/shallow drillhole data.

The shallow horizontal event is a refraction event from the base of Mawson's deep cover profile (base of weathering). Although this is not reflection energy, stacking refractions at near offsets can sometimes lead to a meaningful geological interpretation, even when it is assumed that the event is a reflection (Steeples and Miller, 1998). As observed in both Figure 5 and Figure 8, this base-of-cover event exhibits structure which is a valuable source of additional information which will better inform the geological model. The depth of this event in the re-processed PSDM volume is consistent with the depth of cover derived from multiple sources of information including inversion of gravity data, statics calculations, and drilling. This event is not present in the legacy processing (Figure 4 and Figure 7).

The reflector dipping from left to right in both inline and crossline directions is the Mawson Fault plane. Understanding the geometry and relative timing of this fault is critical to developing a valid geological interpretation which will properly inform future exploration and mining decisions. Note that the fault-plane itself is the reflector and the areas of interest for economic development (Figure 6 and Figure 9) are generally not reflective in a seismic sense.

After interrogation of both datasets, the legacy processing appears smoother than the re-processed version. As a consequence, large events; for example, the Mawson Fault, are potentially overrepresented and more subtle events can be lost. The re-processing clearly shows numerous truncations/breaks/offsets in the reflectors which gave Legend confidence in extending known and inferred structures and its overall understanding of the project. The Mawson fault is one of these structures, however, there is evidence of similar repeated sub-parallel structures at depth, as well as multiple and repeated conjugate faults. The re-processing has aided in the ability to interpret responses which were theorised to be similar to already defined magmatic mafic-ultramafic signatures and also, earlier structural features that may be related to the propagation and emplacement of the Mawson magmatic system. The difference between the two datasets is particularly evident in Figure 7 and Figure 8 where the re-processed data exhibits fewer migration artefacts.

To date, there has been no additional drilling to test specific features observed in the re-processed volume that were not evident in the legacy volume. However, utilising existing drilling and other sources of data, there is confirmation that the re-processed volume better supports Legend's geological model and inferred geological history established from systematic diamond and reverse circulation drilling. While there was support in the legacy volume, there were also some inconsistencies compared to what was expected across the project.

The contrasts in the final PSDM images can be attributed to different choices in processing modules and parameters. Unfortunately, specific parameters for many of the legacy modules are unknown and therefore results are not re-produceable. Consequently, robust conclusions about the causes of the differences in the images cannot be drawn. Nonetheless, this case-study illustrates the benefits of re-processing seismic data in a minerals context, which can provide both confirmation of previously imaged structure, and additional information which may alter or enrich any subsequent geological interpretation. Given the cost of re-processing is insignificant against the cost of acquisition, the benefits of re-processing are often worth the small extra costs involved.

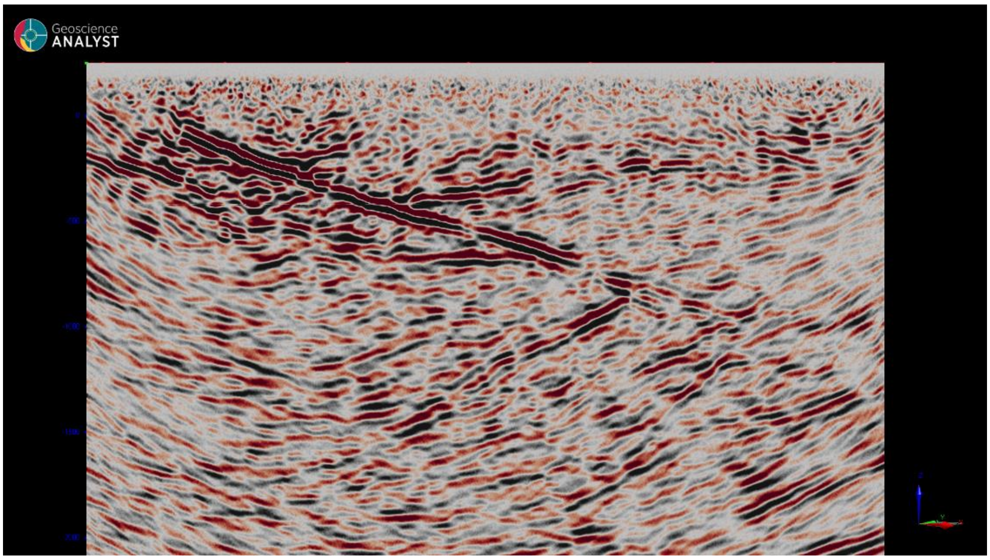

Figure 4. Legacy processing PSDM inline. V:H = 1.

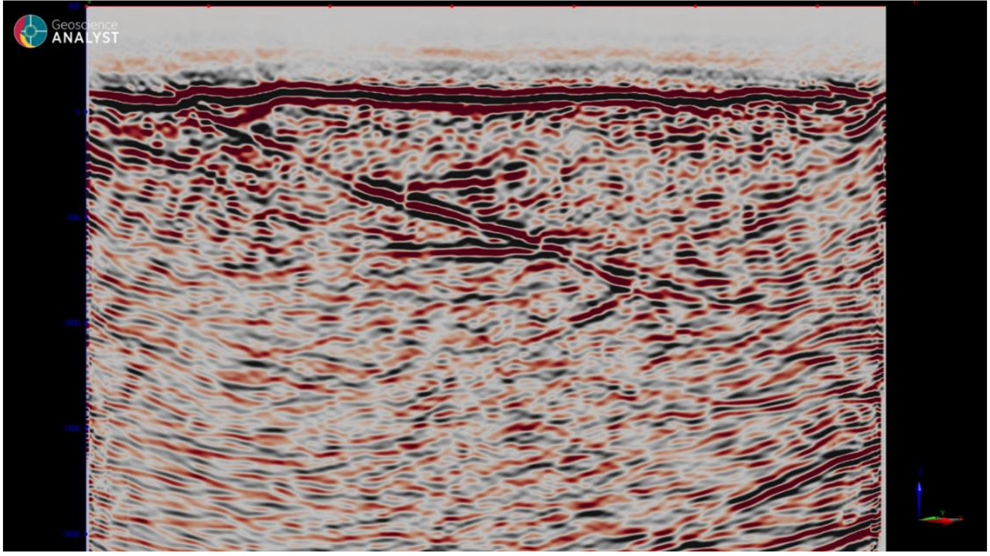

Figure 5. Re-processed PSDM inline. V:H = 1.

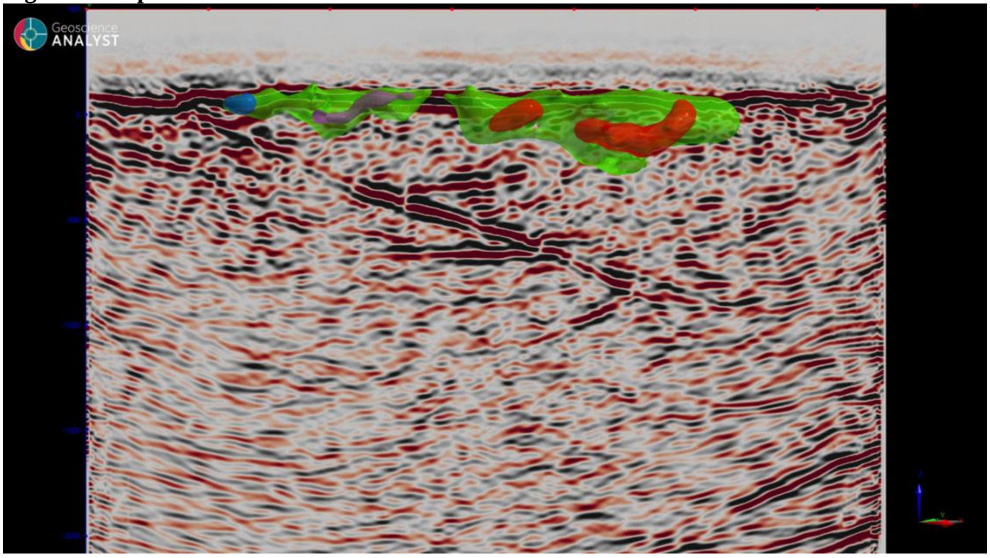

Figure 6. Re-processed PSDM inline with intrusion model overlay. Blue, purple and red volumes are the inner ultramafic core zones, which lie within the overall mafic-ultramafic chonolith (green). V:H = 1.

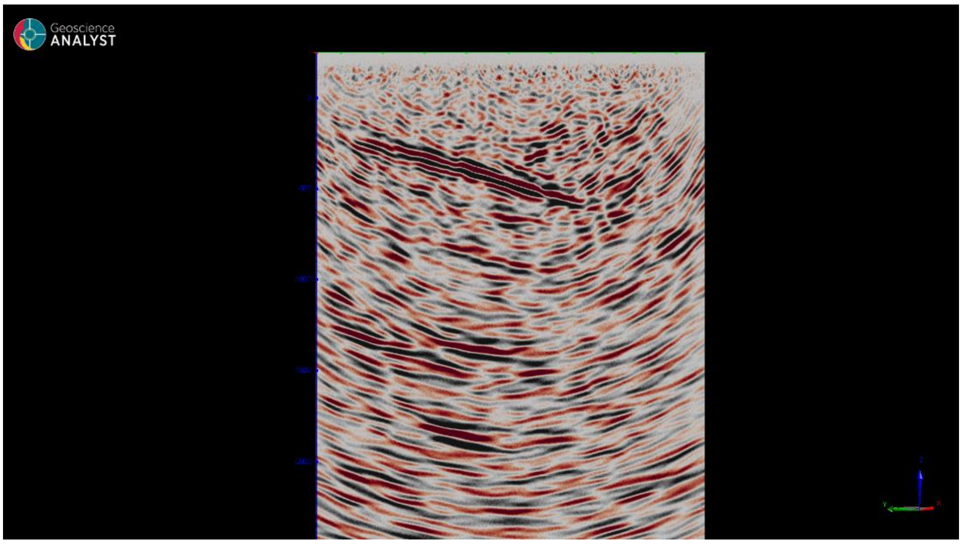

Figure 7. Legacy processing PSDM crossline. V:H = 1.

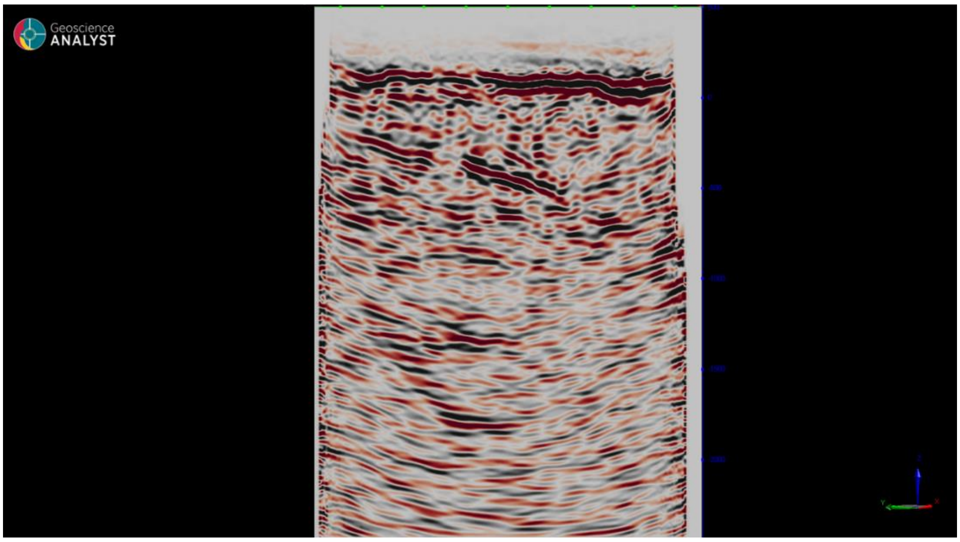

Figure 8. Re-processed PSDM crossline. V:H = 1.

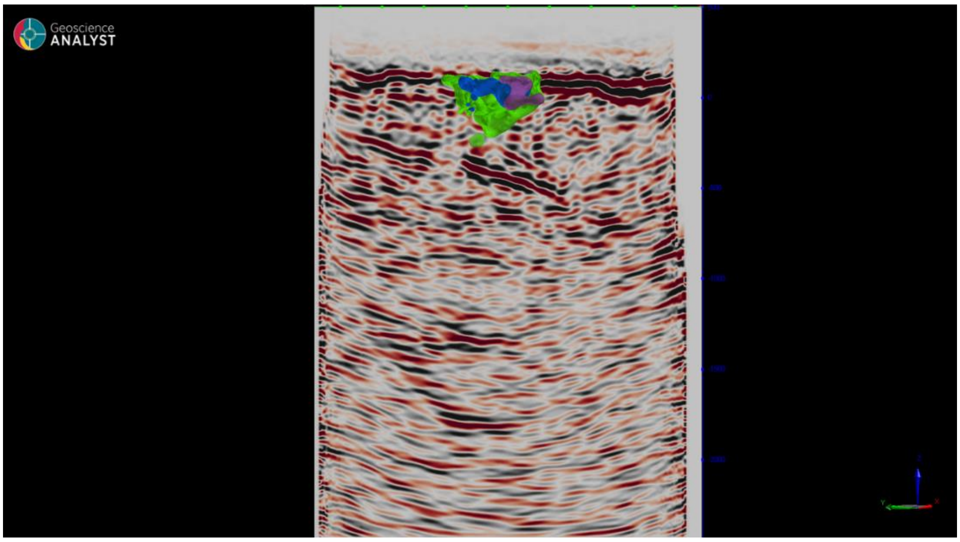

Figure 9. Re-processed PSDM crossline with model overlay. Blue, purple and red volumes are the inner ultramafic core zones, which lie within the overall mafic-ultramafic chonolith (green). V:H = 1.

CONCLUSIONS

Re-processing of the Mawson 3D seismic volume has provided new insights to Legend's understanding of the Mawson prospect. Structures observed in the re-processed version are a better representation of Legend's geological understanding compared to those observed in the legacy processing. Further drilling is required to properly understand the features uncovered in the re-processing. As with any project, ongoing drilling and new information may shift of alter the understanding of the project.

More broadly, this case-study illustrates that the seismic method can be applied in the minerals exploration context as a relatively economic method of broad-scale structural imaging which can fill in the gaps between sparse data points acquired from relatively expensive drilling programs. In addition, re-processing of data which is already acquired can provide support for previously generated models as well as additional information which can inform future models.

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