Maximising the value of 2D hard rock seismic acquisition at Escondida Porphyry Copper Mine

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**SUMMARY**

In mining areas with limited previous seismic acquisition, 2D seismic lines are often acquired to determine viability of the method and optimal survey parameters in advance of a more comprehensive 3D survey. Consideration of the design and acquisition strategy can allow additional value to be leveraged from the nominally 2D data. At Escondida, four 2D lines were processed to yield a pseudo-3D volume over a portion of the survey area, allowing improved structural interpretation above what could be achieved from 2D imaging alone.

**Key words:** hard rock seismic, porphyry, structure.

**INTRODUCTION**

Hard rock seismic acquisition has increased in recent years with numerous surveys undertaken. As a result, acquisition designs, provider and equipment availability continue to improve. Nonetheless, design often remains limited by several factors: 1) access at mine sites can often be difficult due to operational interferences, the necessity to avoid existing mine infrastructure, and the limited familiarity of the minesite teams with the logistical and safety requirements for seismic making it challenging for them to assist with facilitation, 2) low channel count availability in geographic area with weaker commercial demand reduces or precludes acquisition of the large offsets required to optimise the use of refracted waves and to image steep reflector dips without compromising station spacing requirements for spatial aliasing, and 3) lack of historic surveys and/or petrophysical information in the host geology to guide equipment and design parameter selection.

Frequently these design challenges are mitigated through the acquisition of a 2D seismic trial prior to consideration of a larger 3D seismic program. Mobilisation of equipment and personnel is a significant portion of the cost of seismic at most minesites and the cost of a 2D survey is frequently still large. Further, including 2D acquisition in the project plan inevitably delays the 3D program and, as a result, may commercially impact the minesite due to the resulting delay in the delivery of the sought-after geological information from the 3D survey. It is therefore necessary to attempt to maximise the information obtained from 2D surveys in these environments.

Escondida is one of the largest open pit mines in the world, with the Escondida pit extending to a depth of >600 m and covering an area ~4x3 km in size. As the pit continues to expand, structures must be accurately mapped to allow appropriate geotechnical management. In 2018, 2D seismic was trialled over a site proximal to the Escondida pit to determine the applicability of the method in the Escondida geology and to determine appropriate acquisition parameters for a future 3D survey.

An unconventional acquisition of the 2D design allowed processing of the data as a pseudo-3D volume at depths of >800 m. While the 2D data showed the presence of numerous seismic reflectors at Escondida, the complex structure was most clearly illuminated by the pseudo-3D volume.

**METHOD AND RESULTS**

In the area selected for the 2D trial survey, seismic source and receiver access was significantly limited by mining infrastructure. Four 2D lines were ultimately identified as accessible, totalling a length of 21.2 km (Figure 1), however, it was necessary to break the lines in several places due to obstructions such as mine waste dumps, conveyor belts and active haul roads. The logistics of these numerous breaks presented a communication difficulty for the available recording system, which was a cabled system. A total of 6 breaks were required; the longest gap was 1.4 km but would have required >2.4 km of cabling to circumnavigate the obstruction and allow connectivity between the receivers on the active line. The number, size, and shape of these gaps meant that it was not possible to physically or wirelessly connect the cable system across all of these, and an alternative solution was needed. The cabled system was supplemented with nodal geophones for a total channel count of 3500, solving the communications problem and allowing the full receiver spread to be live during acquisition. This eliminated any need to double-shoot shots for later merging, reducing the acquisition burden, and, more critically, allowed a 10.9 km² portion of the survey to be processed as a 3D volume.

Signal penetration through the unconsolidated cover material, underlying sedimentary basin, and generally strongly altered basement required significant signal, particularly in light of the proximity of the survey to the noise from active mining operations. Design parameters were optimized for the 2D lines, with receivers at 5m intervals and shots at 10 m intervals, for a nominal fold of 260. The resulting pseudo-3D volume was binned in 10 m bins, yielding a fold of ~30-100 in most places. Two 62,000 lbs vibrator sources were used in a crossline configuration to deliver a 32s linear sweep from 8-120 Hz for each shot.

Processing was initially completed using conventional 2D methods to produce images of the four 2D lines and, later, completed in 3D to produce a volume. Both processing flows employed tomographic static corrections (e.g. Schijns et al., 2009), 2D noise attenuation, velocity analysis, muting and post
stack time migration, prior to time-depth conversion. Processing in 3D, however, additionally allowed the data to benefit from higher order noise attenuation in the cross spread domain and resulted in significant additional noise reduction (Figure 2).

![Figure 1](image1.png)

**Figure 1.** Survey geometry showing 2D line geometry and resulting 3D fold coverage.

![Figure 2](image2.png)

**Figure 2.** Shot gather in the cross-spread domain a) before and b) after 4D matching pursuit noise attenuation.

While the 2D processing did show significant reflectivity within the target area, structural interpretation of the 2D lines was complicated by the presence of off-line reflections from the 3D porphyry geology, and the frequently oblique strike of structures to the 2D line orientations, as Escondida has a complicated deformation history with four separate structural trends identified. The 3D processing allowed the calculation of more advanced attributes, including variance filtering and ant-track (Petrel), improving detection and discrimination of structures. The seismic interpretation was additionally significantly aided by the ability to visualize depth slices (Figure 3).

**CONCLUSIONS**

Trial 2D seismic lines are frequently acquired in the scoping stages of 3D hard rock seismic programs but, despite the perceived high cost of seismic acquisition, the potential of these data sets is often under realized. Where multiple 2D seismic lines are acquired, recording of data on the broadside or offline receivers, in conjunction with the standard recording of the inline receivers, adds limited additional cost but can be used to provide significant additional value to the program. Although the resulting pseudo-3D data has limited fold, offset, and azimuthal distribution within the seismic gathers compared to the 2D data, the processed volume nonetheless shows excellent correlation with the known structure and geology. The pseudo-3D data allows improved decision-making prior to the acquisition of a true 3D survey than would be possible from the pure 2D lines alone.

![Figure 3](image3.png)

**Figure 3.** Depth slice through the pseudo-3D seismic attribute volume (ant-track).

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