Direct imaging of alteration with high-resolution hard-rock 3D seismic data at the Darlot Gold Mine

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SUMMARY
The Darlot gold mine is an Archean orogenic deposit located in the world-class gold and nickel terrain of the Yandal granite-greenstone belt within the Yilgarn Craton in Western Australia.

In 2016-2017, HiSeis designed, acquired and processed a high-resolution 3D seismic survey centred on the Darlot-Centenary mineralised system with the objective of improving lithological and structural interpretation of the project area and to support targeting of mineralisation.

The capability of modern 3D seismic surveys to image formational contacts and structures in hardrock environments has had a game-changing impact on the effectiveness of brownfields exploration programs because the geometry of mineralised systems can now be directly imaged over large volumes of ground. More specifically, partially-preserved relative seismic amplitudes can allow the direct imaging of alteration associated with gold mineralisation in fertile structures, allowing discrimination between these and barren structures and dramatically improving drilling success rates.

We present the results of a structural interpretation of the seismic data which focused on identifying drilling targets prioritised with seismic amplitude variation.

Key words: 3D Seismic, hardrock, gold, alteration, structural interpretation.

INTRODUCTION
The Darlot gold mine is an Archean orogenic deposit located in the world-class gold and nickel terrain of the Yandal granite-greenstone belt, part of the Yilgarn Craton in Western Australia (Figure 1). Total production from Darlot and the associated Centenary deposit since 1988 has been 17.8 Mt at 4.8 g/t Au for 2.8 M Oz of contained gold. The mine currently has a resource of 6.2 Mt at 4.8 g/t Au with a recently increased ore reserve of 1.92 Mt at 3.5 g/t. Mining face grades of 26 g/t to 35 g/t from the recently discovered (February 2018) ‘Oval West’ area and additional ounces from nearby exploration successes indicate the potential to expand the Darlot reserve base.

Gold mineralisation of the Darlot and Centenary deposits is typically associated with narrow, flat extension veins controlled by brittle-ductile D2 and D3 faults and strain partitioning at areas of contrasting competence. Host rocks are the magnetic Mount Pickering dolerite, which overlies felsic volcanioclastic sediments and felsic intrusive rocks, all of which are geochemically and rheologically favourable to gold precipitation. Mineralisation is associated with disseminated pyrite found in the albite, silica and carbonate alteration selvages of structures and veins. Lamprophyre intrusions occur throughout the deposit with a variety of orientations (occurring pre-, syn- and post-mineralisation); despite being barren, they have a spatial association to mineralisation.

Figure 1. Geology of the Darlot Gold Mine area. The red polygon shows the extent of the 3D seismic survey, and the dashed line shows the El Dorado Shear. Mafic igneous units are shown in various shades of green. (Red5)

METHOD AND RESULTS
A 3D seismic survey centred on the Darlot-Centenary mineralised system was acquired by Goldfields in 2016-2017 (Figure 2). The objective of the survey was to rapidly identify potential mineralisation in the vicinity of the existing underground infrastructure as the project neared the end of the expected mine life. Circumstances arose in which Goldfields elected to divest the mine before processing of the seismic data was completed. Red5 purchased the project and inherited the un-interpreted dataset.

The effectiveness of reflection seismic depends on the presence of contrasts in acoustic impedance (AI) (density × velocity) and use of appropriate survey geometries in order to capture reflections. An expedited de-risking program conducted prior to acquisition included sonic velocity and density measurements on core, which were used in conjunction with 3D geological modelling to forward model the seismic response of the rock volume. This work indicated that mineralised structures and alteration zones, as well as faults, felsics, lamprophyres and dolerites would all exhibit strong acoustic impedance contrasts with adjacent units and would be good seismic reflectors.
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3D seismic data was acquired and processed with prestack time migration and converted to depth using a derived velocity model and fine tuning against the well-imaged underground workings. The final, processed seismic volume covers an area of 25 km$^2$, with interpretable resolution extending from 300 m to 3000 m depth with a cell size of 15 x 7.5 x 4 m.

In addition to the seismic reflection data, seismic tomography provided useful geotechnical and hydrogeological information in the upper 300 m of the surveyed volume. Of particular use was the depth-to-fresh rock information, used to help constrain potential field inversion modelling (See Darlot 3D Seismic and Potential Fields, Pears et al.)

Gocad was used to carry out data compilation and seismic interpretation wireframe modelling. Gocad’s 3D GIS functions were used to prioritise the hierarchy of the identified targets.

INTERPRETATION

Seismic data identifies the position and orientation of contrasts in AI (the product of velocity and density), producing reflections where abrupt contrasts in AI occur. This paper focuses on interpretation of the seismic reflection data with respect to identifying structures likely to host gold.

High-resolution seismic data allows the direct identification of structural elements in a deformed volume of rock via several factors:

- Termination of reflectors,
- Offset of reflectors,
- The local juxtaposition of two seismically dissimilar rock types,
- Sub-planar destruction of reflection amplitudes,
- Direct reflection due to reduction of Vp in zones of poor RQD,
- Direct reflection due to Acoustic Impedance contrast at the alteration halo front, and,
- Mineral alignment in shears producing anisotropy of Vp.

Rock property measurements on core drilled from the Darlot deposit indicate alteration has a direct effect on AI at the mine area. HiSeis, Goldfields and Red5 geologists have collected numerous coincident Vp and SG measurements and established a clear link between albite, carbonate and silica alteration and a modification of AI that is strong enough to produce a seismic reflection.

Alteration is known as a vector for identifying gold mineralisation since mineralising fluids tend to alter the rocks through which they travel. The seismic method can delineate alteration because alteration itself often modifies the density and/or seismic velocity of the rock hosting that alteration.

By defining faults within the seismic volume and then assessing the reflectivity of those faults, the seismic dataset allows for rapid target identification and prioritisation.

SUPPLEMENTARY DATA

Apart from the seismic data, there is a large amount of conventional exploration data, including:

- Geochemistry,
- Exploration Drilling,
- Aeromagnetics (20 m flight height, 25 m spaced lines)
- Ground gravity (200 m station spacing), and,
- Surface geological mapping.

The targets derived from the seismic interpretation exercise are shown in Figure 3.

Figure 2. Oblique view of the Darlot seismic cube, looking north.

Figure 3. Structural drill targets derived from seismic interpretations

Figure 4. Alteration haloes revealed as seismic reflections in fault planes. (Depth slice 318, approximately 1300 metres below surface)

The application of Gocad’s 3D GIS functionality is used to further refine those priorities, using factors such as proximity to existing infrastructure, favourable orientations assessed from earlier work and the relative amplitude of the seismic reflection.
Figure 5 displays the seismic reflection property painted onto the Oval Fault surface. Drilling targeted the high amplitude reflections on the fault, which proved to be associated with approximately 30 metres of alteration enveloping the fault plane (Assays are unknown at the time of writing.)

Figure 5. CAX0037 targeting high amplitude seismic reflections on the Oval Fault (Looking SE)

Other high priority targets have been drilled recently. CAX0051 was drilled to intercept a target identified in the seismic data. A maximum Au value of 0.95m @ 9.8ppm Au was achieved at the expected target depth. CAX0049 also successfully intersected targets identified in the seismic data.

CONCLUSIONS

This paper provides a demonstration of the value of high-resolution geophysical data when assessing the potential for brown-fields exploration in a mature gold mine.

Seismic reflection surveys enable the direct detection of alteration haloes associated with gold mineralisation in the Darlot Gold mine, enabling the efficient targeting of mineralisation with drilling and reducing the cost of resource definition drilling programs by reducing the number of holes required to locate and define structures.

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