Advances in Seismic Reflection as an Exploration Tool in Hard-Rock Mining

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The last 10 years...

Status 2007
- Applied research and surveys led by Curtin University
- Strategies developed to address:
  - statics
  - velocity analysis
  - Discontinuous reflectors
  - “off-the-plane” reflectors
- Recognition that interpretation begins during processing
- 2D surveys successfully mapping mineralised geology

Status 2017
- IP from Curtin University commercialised by HiSeis
- >20 minerals 3D surveys worldwide
- Better understanding of rock property variability and importance of alteration
- Regularly imaging steep dipping geology and structures
- Demonstrated ability to image below surface obstructions
- Ongoing learning and development
## Minerals Seismic Worldwide

**Types**

<table>
<thead>
<tr>
<th>Commodity</th>
<th>Type</th>
<th>Note: Only HiSeis projects shown, many additional surveys have been completed particularly in South Africa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gold</td>
<td>Orogenic, Epithermal</td>
<td></td>
</tr>
<tr>
<td>Copper</td>
<td>VMS, Porphyry, Orogenic</td>
<td></td>
</tr>
<tr>
<td>Zinc</td>
<td>Sedex, VMS</td>
<td></td>
</tr>
<tr>
<td>Nickel</td>
<td>Komatiitic, Layered intrusive</td>
<td></td>
</tr>
<tr>
<td>Iron ore</td>
<td>BIF</td>
<td></td>
</tr>
<tr>
<td>Uranium</td>
<td>Unconformity</td>
<td></td>
</tr>
<tr>
<td>Lithium</td>
<td>Pegmatite</td>
<td></td>
</tr>
<tr>
<td>Rutile</td>
<td>Mineral sands</td>
<td></td>
</tr>
</tbody>
</table>
Implementation strategy for hard-rock seismic reflection

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What causes reflections?

- Reflections occur at abrupt changes in acoustic impedance

- Acoustic Impedance (AI) = Density ($\rho$) * Velocity (V)

Eg.
- Bedding planes
- Unconformities
- Intrusions
- Alteration zones
- Faults
- Shears
- Large stopes
- Massive Sulphides
- Anywhere there is an abrupt change in AI

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Rock property measurements

- Measure transit time through core, half core or hand specimen
- 100-200 samples per day
Correlation with other datasets


depth

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Evidence for impedance contrast associated with alteration

Enhanced reflectivity

- Mafics
- Felsic
Evidence for impedance contrasts within fault zones

<table>
<thead>
<tr>
<th>Depth</th>
<th>Vp</th>
<th>SG</th>
<th>AI</th>
<th>Lithology</th>
<th>RQD</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4000m/57000</td>
<td>2.7</td>
<td>3.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>600.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>700.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>800.0</td>
<td></td>
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</tbody>
</table>

Fault zone

- Mafics
- Felsic
Case History 1
Exploration around a mature mine - Darlot
Darlot – orogenic gold

Darlot DDH1

Dolerite
Sediments

Acoustic Impedance

Depth (m)
## Darlot 3D seismic stats.

<p>| | |</p>
<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Extent</td>
<td>5.5km x 4.5km</td>
</tr>
<tr>
<td>Depth imaged</td>
<td>&gt; 3km</td>
</tr>
<tr>
<td>Volume</td>
<td>75km³</td>
</tr>
<tr>
<td>Cell/Voxel size</td>
<td>15m x 7.5m x 4m</td>
</tr>
<tr>
<td>Number of voxels</td>
<td>~165 million</td>
</tr>
<tr>
<td>Cost</td>
<td>~ A$2.4M</td>
</tr>
<tr>
<td>Time conception to interp ready</td>
<td>6 months</td>
</tr>
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</table>
Case History 2

Investigating geological architecture

Mt Elliott
2D Seismic Reflection Surveys - adding the depth dimension
HiSeis Processing

16km

10km

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Seismic interpretation

SMIBRC
WH Bryan Mining & Geology Research Centre
Deep Mining Queensland Prospectivity Analysis in the Southern Cloncurry Belt
Seismic without interpretation overlay
Summary

- Understanding the rock properties is key to interpretation
- Alteration is a key control on seismic rock properties
- Seismic can be effective in steep geology
- Seismic very effective at mapping structures
  - flexures
  - intersections with key units
  - intensity of alteration
  - timing
- New tool for mineral exploration especially as we go deeper
The Opportunities

- Better deep targeting in areas of known endowment
- Faster screening around initial discovery
- Better conceptual understanding of geology and mineralisation
- Better mapping of structures for mine planning and mine safety

➢ Faster, more cost effective exploration
➢ Reduced geotechnical issues
➢ Better optimised infrastructure capacity and placement
Acknowledgements