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 (formed 2009)
- >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
Presentation Outline

- Background
- Rock properties
- 2 Case studies
- Conclusion
HiSeis/Curtin University Minerals Seismic Projects* Worldwide

* Includes 2D, 3D and de-risking projects
Implementation strategy for hard-rock seismic reflection

- **Investigation**
  - Rock properties
  - Numerical simulations

- **Optimisation**
  - Borehole surveys
  - Source testing
  - 2D lines

- **High-resolution 3D imaging**
  - 3D survey and processing

- **Value accumulation**
  - Data integration
  - Collaborative interpretation

Value add

Time
What causes reflections?

- Reflections occur at abrupt changes in acoustic impedance.

- Acoustic Impedance (AI) = Density (ρ) * Velocity (V)

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

• Measure transit time through core, half core or hand specimen

• 100-200 samples per day
Correlation with other datasets


depth
Evidence for impedance contrasts within fault zones

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>Vp (km/s)</th>
<th>SG</th>
<th>AI</th>
<th>Lithology</th>
<th>RQD</th>
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- **Vp**: 4000 m/s
- **SG**: 2.7, 3.05
- **AI**: 11, 21
- **RQD**: 0, 100

**Legend**
- Mafics
- Felsic

**Fault zone**
Evidence for impedance contrast associated with alteration

Enhanced reflectivity
Cracow 3D Seismic Survey

Proposed Survey Area
Source lines shown in red, Receiver lines shown in blue

- Source lines 90m
- Receiver lines 75m
- 30m Shot interval
- 15m Geophones

Seismic Sources
- 22,500lb Inova Univibe
- Explosive (150gm buried charge)
Cracow – epithermal gold
Cracow – epithermal gold

Acoustic Impedance AI

Alteration Intensity

Lithology

Andesite Fragmentals

Andesite lavas
Cracow – epithermal gold
Cracow – epithermal gold
Vertical Section from 3D Seismic Cube - Preserved Amplitude Processing

Overlying Volcanics
Interbedded Andesitic Lavas and Fragmentals
Note: “white snakes”
Increasing alteration
Reflections due to acoustic impedance (density*velocity) change across boundary between fragmentals and lavas
Cracow – epithermal gold
Vertical Section from 3D Seismic Cube

White snakes similar to mineralised zone had not been tested despite the filed being known for nearly 100 years.
Darlot – orogenic gold
Darlot – orogenic gold

- Acoustic Impedance
- Dolerite
- Sediments

Depth (m)

Darlot DDH1
Darlot – orogenic gold

Darlot DDH1

Vertical section through seismic cube

Correlation between dolerite-sediment boundary and strong seismic reflector

V:H = 1:1
Darlot – orogenic gold

Darlot DDH1

Vertical section through seismic cube

V:H = 1:1

2km
Darlot – orogenic gold

Horizontal “depth slice” through seismic cube

600m below surface

5.3km

4km
Darlot – orogenic gold
Summary & Key Learnings

Understanding the rock properties is key to interpretation.

Alteration is a key control on seismic rock properties.

Seismic very effective at mapping structures.

Seismic is an effective new tool for mineral exploration, especially as explore/mine deeper.
**Standard Method**
(Drilling alone)

- Detect point locations of contacts and structures
- Resolution of conventional minerals geophysics degrades rapidly with depth
- Each hole tests a small area and provides limited context for further exploration
- Long timeframe ~1 x 1km hole per month
- DDH ~ $250k per km ($5-10m per km² for 200m drill centres)

**Problem**
(Deep Exploration)

**Seismic Solution**
(Seismic + Drilling)

- Map contacts and structures in 3D
- Resolution is maintained at depth
- Each 3D seismic survey screens multiple km³ and provides framework for subsequent exploration
- 10km² acquired and data processed within 3 months (fast screening)
- 3D survey cost ~$200k/km² (0→2km²)
- Fills the gaps between drill holes
- **Cost effective!**
Acknowledgements

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& HiSeis Staff