Seismic and Mineral Exploration: Time for a New Relationship

Don Pridmore
A late starter….

Strong demand for expansion of mining activities:
Necessity to delineate extension of known mineralisations at greater depths
Need to define new exploration targets, often beyond the reach of potential field methods
Exploration of deeper targets by drilling – too expensive
No choice - try seismic methods

Seismic exploration in Hard Rock environments

Moore, et al. Science 16 November 2007:

3D Seismic: Nankai Trough subduction zone

Slumps

Accretionary prism thrusts

Décollement

Oceanic crust

Megasplay fault

Moore, et al. Science 16 November 2007:
OUTLINE

• Seismic reflection method
• Performance in hydrocarbon exploration
• Why has it not been successful in mineral exploration?
• Derisking the application of seismic
• Case histories
• Summary
Seismic Data acquired as either ‘2D’ or ‘3D’

3D ‘Greenfields’

3D ‘Brownfields’

2D Seismic Reflection
Seismic Acquisition
HOW DOES IT WORK?

• Reflections occur at changes in acoustic impedance (Density*Velocity).
  Eg abrupt changes in:
    lithology and alteration
    at
    bedding planes, faults, shears, intrusions etc
SYNTHETIC MODELLING

- Wide scattering

- Forward modelling of possible geological scenarios is crucial for survey planning

- 3D effects
  Implications for targeting
SEISMIC DETECTABILITY

**P-wave Velocity times Density**

- Felsic volcanics
- Massive sulphides
**WHAT CAN SEISMIC SEE?**

*Resolution maintained with depth*

**Minimum resolvable bed thickness**
- ~ 25m (top and bottom resolvable)

**Minimum detectable bed thickness**
- ~ 5m or less

**Minimum fault throw**
- ~ 10m

**Horizontal Resolution**
- ~ 25m across
• Can investigate to large depths
• Provides continuous maps of layer boundaries and structures
• High Resolution
• Maintains resolution with depth
SEISMIC IN MINERAL EXPLORATION

With exceptions rarely used because:

• Technical issues

  Impact of high velocity and complex geometry on ‘learned behaviour’ from hydrocarbon exploration

  Lack of understanding of ‘seismic’ rock properties

• Cost relative to alternatives (drilling, geophysics)
THE OPPORTUNITY

• Faster screening around initial discovery
• Better conceptual understanding of geology and mineralisation
  ➢ Optimise infrastructure capacity and placement
  ➢ More cost effective brownfields exploration
• Better mapping of structures for mine planning and mine safety
HiSeis Innovation

Oil and Gas Seismic
- ‘Simple’ geology
- Seismic proven success

Minerals Seismic
- Complex geology with high velocity
- Adaption of all aspects of the method required
IS SEISMIC SUITABLE AT YOUR SITE?

How do we de-risk a seismic survey?

- Seismic Survey
- Site Visit / Noise Test
- Rock Property Measurements
- Synthetic Modeling
- Vertical Seismic Profiling/ FWS
ROCK PROPERTY MEASUREMENTS

- Measure transit time through core, half core or hand specimen
- Need flat ends
- Multiple samples per rock unit
SONIC AND DENSITY LOGS
SHEAR ZONE SEISMIC LOGS

Velocity  Density  Acoustic Impedance
VSP’s provide the macro-scale linkage between geological/petrophysical variations and the bulk in-situ response measured using surface seismic reflection techniques.
VSP

Strong reflectors in VSP data.
SEISMIC TEXTURE

Strong semi-continuous reflections

Shear

Multiple discontinuous reflections
Objectives

- Map the mineralised shear system
- Generate targets at depth
Figure 1: Section showing lithology and mineralization on traces of BBDE001 and BBDE002 with preliminary interpretation.
CASE STUDY – BULLABULLING

Cross-section on Seismic Line Showing Planned Drill Holes
CASE STUDY – KAMBALDA

Milovan et al 2013

Objectives

• Map subsurface stratigraphy and structure to 1km depth

• Map the basalt/ultramafic contact

• Map structures that offset this surface

• Detect Mineralisation
KAMBALDA FAULTING

Alpha Island fault (previous)
Interpreted fault plane

Alpha Island fault (previous)

Depth slice at 768m

Depth slice at 1266m
HiSeis Data: Kambalda WA

RMS amplitude: extracted 10 m above and 4 below the contact
Regional Geology: Iberian Pyrite Belt

- Known Sulphide Deposits
  - Shale and Greywacke
  - Volcano-Sedimentary Complex
  - Phyllite-Quartzite Unit

Portugal

Spain

0  25  50 (Km)
Iberian Pyrite Belt: Structure & Stratigraphy

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<td>Late Visean B</td>
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Neves-Corvo: Big Massive Sulphide Deposits

2P RESERVES (30 June 2012)
24.1Mt @ 3.1% Cu
22.7Mt @ 7.4% Zn, 1.7% Pb, 70 g/t Ag
3D SURVEY GRID OVER MINE
3D Seismic Survey Depth Slice at 894 m

High Resolution
Rx 90 x 15m
Tx 90 x 45

Survey Block
6.4 x 4.6 km

Note faults cutting Lombador into segments
3D Seismic Survey at Neves-Corvo – Section

- Very good correlation between mineralization and strong reflectors
- Targeting more effective, saving time and money.

NW View of section through Semblana Massive Sulfide

massive sulphide footwall contact
Some success stories

"A high-resolution 3D seismic survey has now been completed over a 21 square kilometer area surrounding the Neves-Corvo mine. Preliminary results have clearly imaged the major Semblana deposit, verifying the effectiveness of this new tool in the search for blind massive sulphide deposits"

*Lundin Mining news release to the Toronto stock exchange. July 21, 2011*

"Based on 3D models created using recently acquired seismic data, 2 new diamond drill holes were planned, each planned to drill to a minimum depth of 600m. A new prospective ultramafic-amphibolite sequence identified below the current deposit and further significant intersections from existing deposit were discovered"

*Announcement from Bullabulling Gold Limited to the ASX, September 6, 2012 and October 30, 2012.*
SUMMARY

Industry Solution
Drilling

• Data in only 1D.
• Slow: 1 month to drill 1km.
• Costly: $250K per km.

Problem
Brownfield exploration at depths greater than 3-500m.

• Detect structures & alteration.
• Directly detect some mineralisation styles.
• Cost competitive @ $250K/km².
• Rapid results.
• Low environmental impact.
• Faster 3D targeting of drilling.

Seismic Solution
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