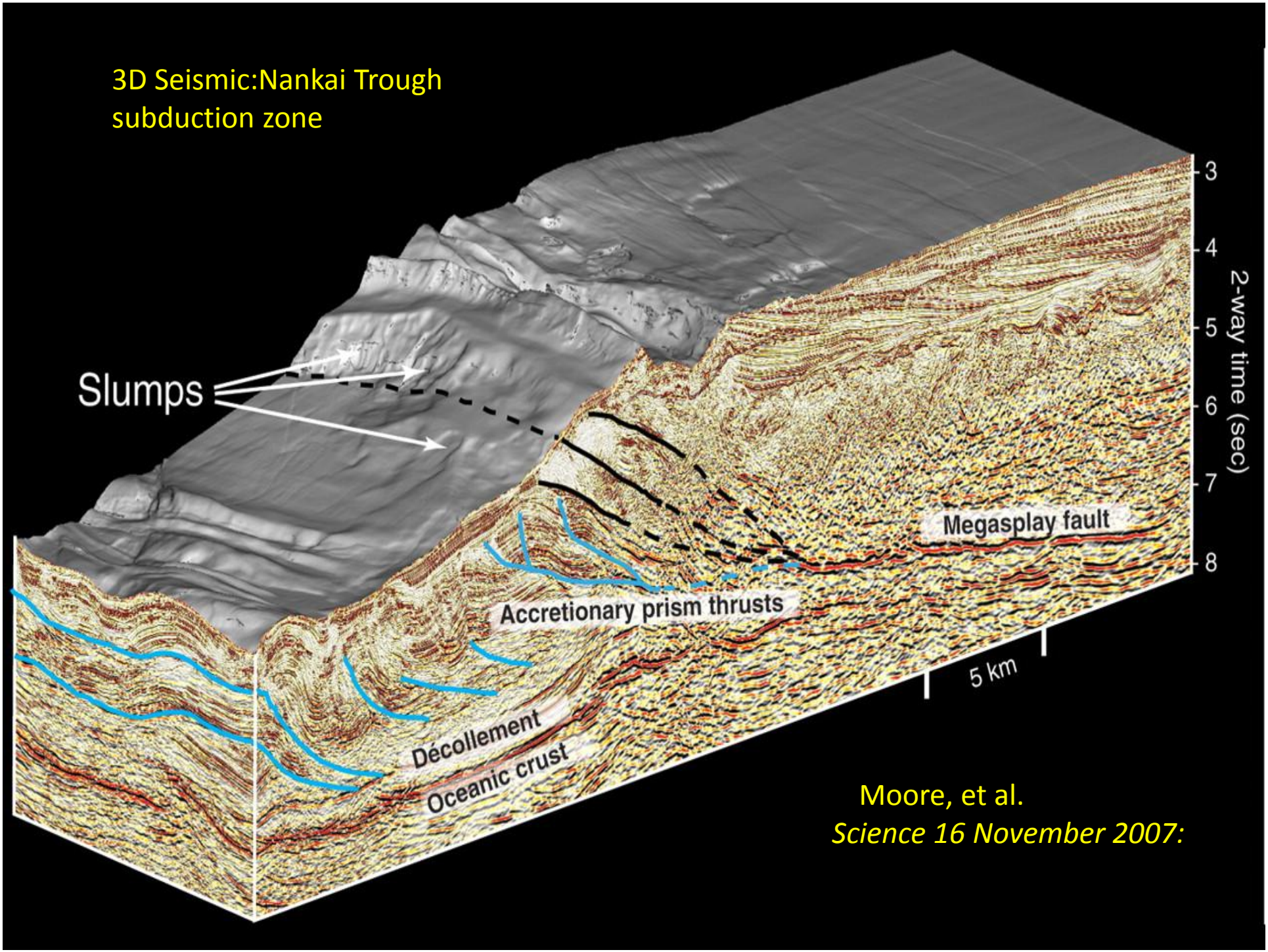
UNLOCKING
RESOURCE
POTENTIAL

# Seismic and Mineral Exploration: Time for a New Relationship


**Don Pridmore**

HiSeis

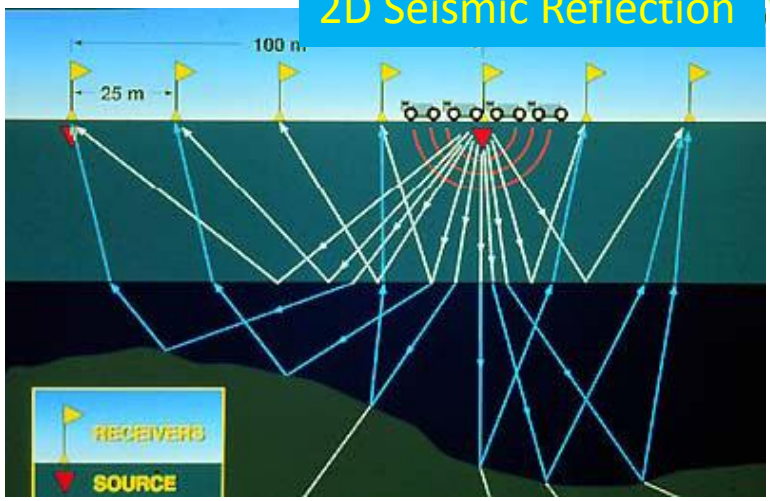

3D Seismic:Nankai Trough
subduction zone
Slumps
Megasplay fault
Accretionary prism thrusts
Décollement
Oceanic crust
5 km
2-way time (sec)
3
4
5
6
7
8
Moore, et al.
*Science 16 November 2007:*

# OUTLINE

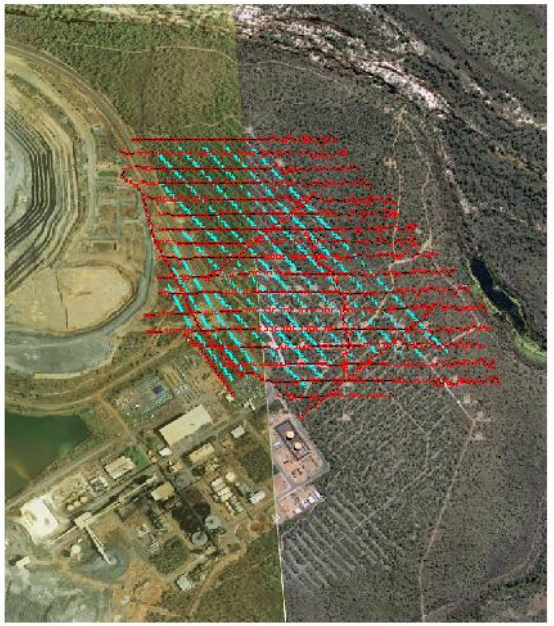
- Seismic reflection method
- Performance in hydrocarbon exploration
- Why has it not been successful in mineral exploration?
- Derisking the application of seismic
- Case histories
- Summary

# Seismic Data acquired as either '2D' or '3D'

2D Seismic Reflection




3D 'Greenfields'



3D 'Brownfields

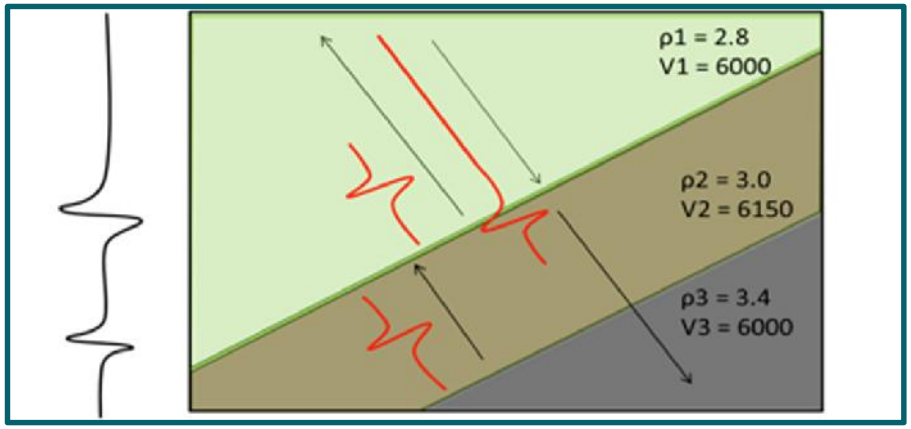
HiSeis

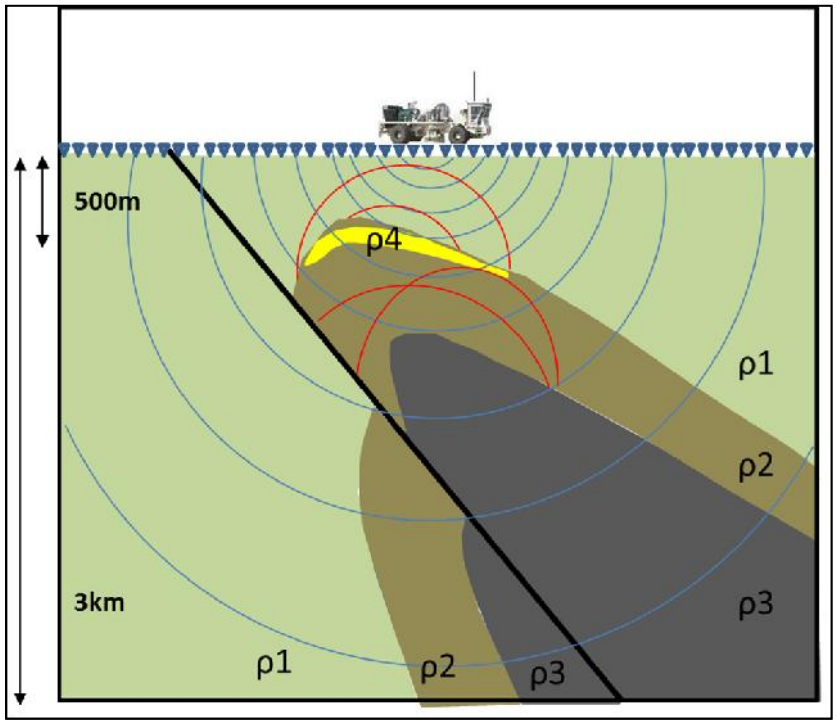
# Seismic Acquisition

HiSeis

# HOW DOES IT WORK?

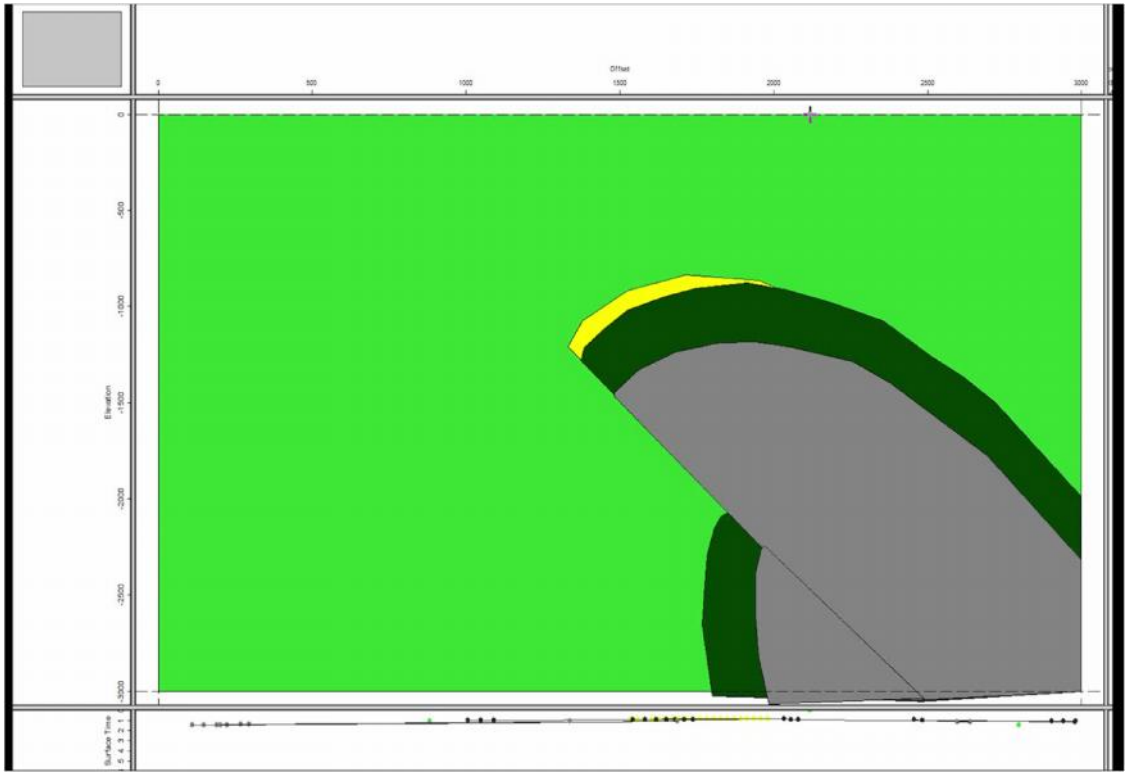
- Reflections occur at changes in acoustic impedance (Density*Velocity).
  Eg abrupt changes in:
  lithology and alteration
  at
  bedding planes, faults, shears, intrusions etc



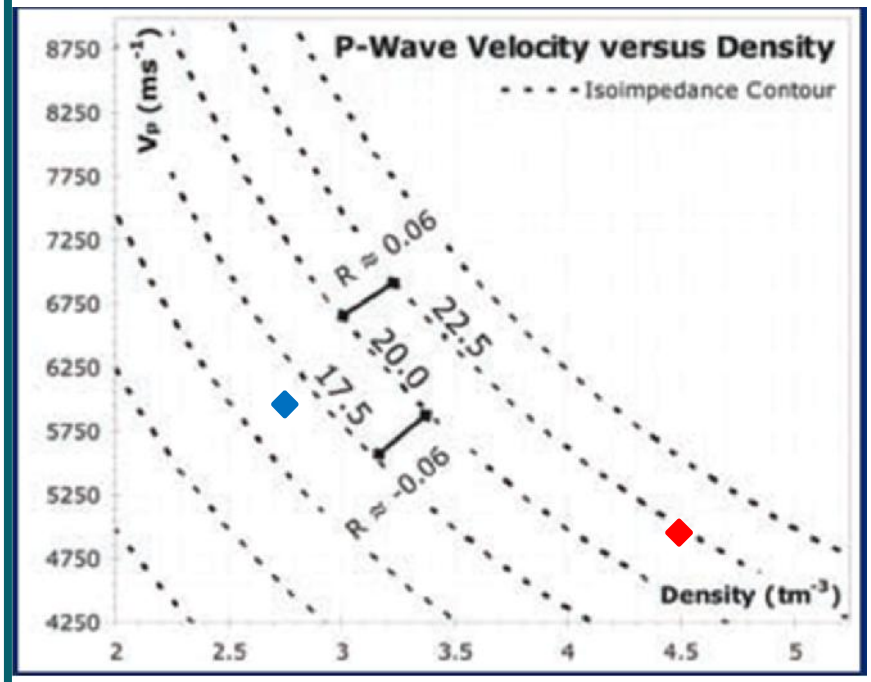
# SYNTHETIC MODELLING

- 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**

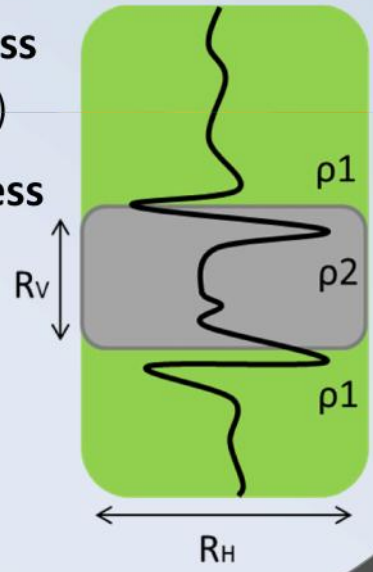
- ~ 5m or less

**Minimum fault throw**

- ~ 10m

**Horizontal Resolution**

- ~ 25m across



# WHY SEISMIC?

- 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)

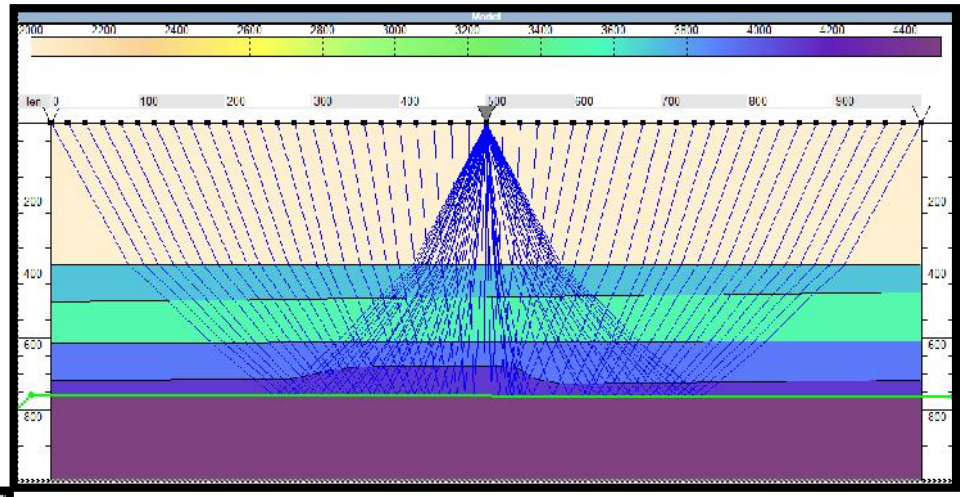
# THE OPPORTUNITY

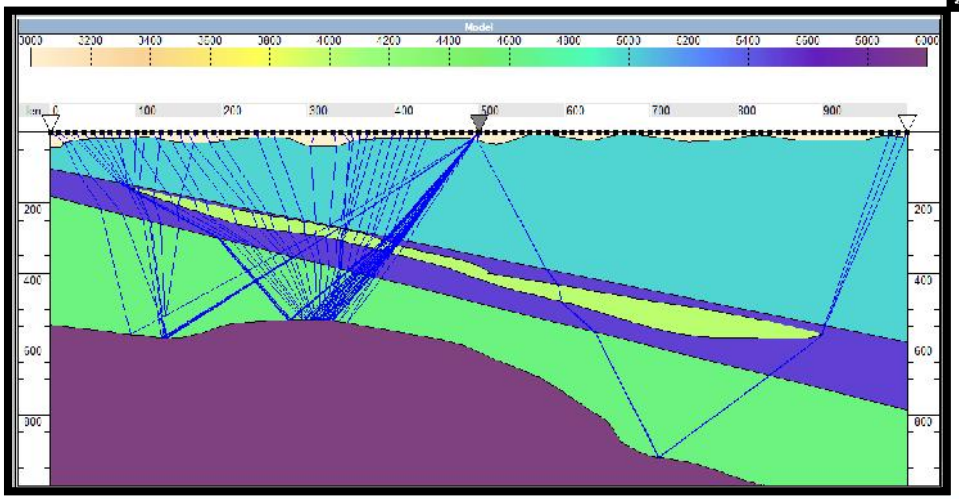
- Faster screening around initial discovery
- Better conceptual understanding of geology and mineralisation
  - ➢ Optimise infrastructure capacity and placement
  - ➢ More cost effective brownfields exploration
- Better mapping of structures for mine planning and mine safety

# 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

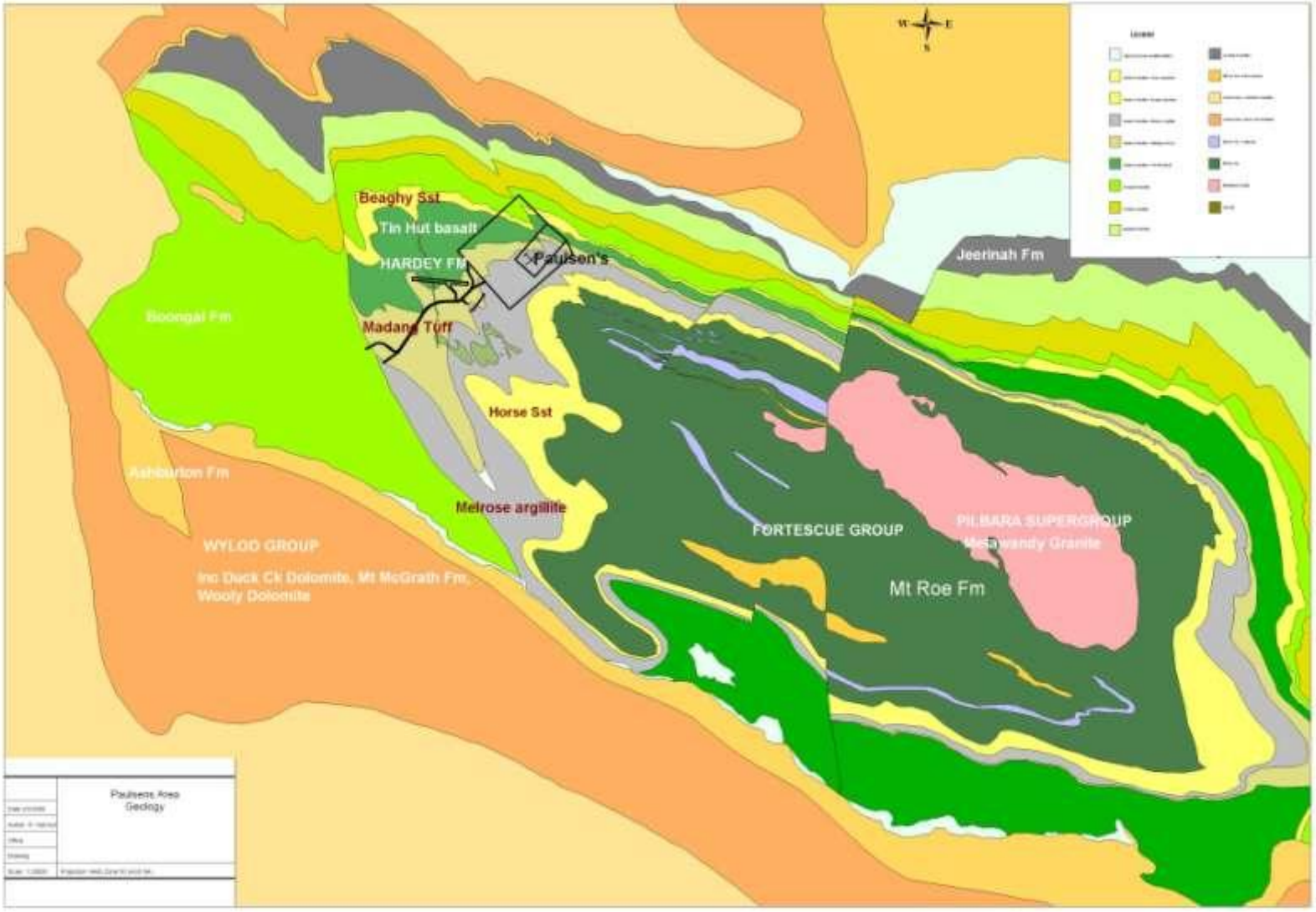
# IS SEISMIC SUITABLE AT YOUR SITE?

How do we de-risk a seismic survey?

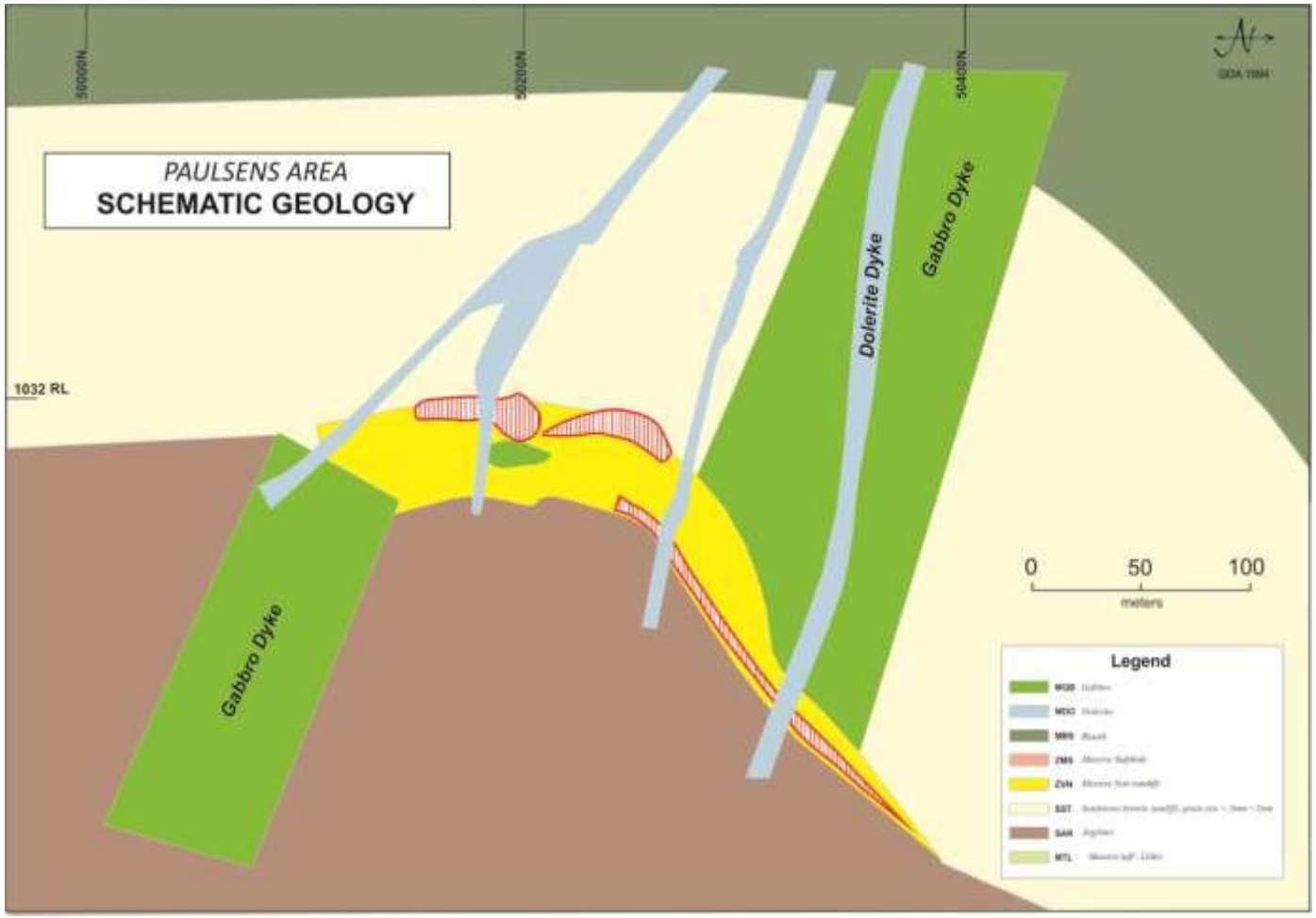
# ROCK PROPERTY MEASUREMENTS


- Measure transit time through core, half core or hand specimen
- Need flat ends
- Multiple samples per rock unit

# PAULSEN'S SURFACE GEOLOGY

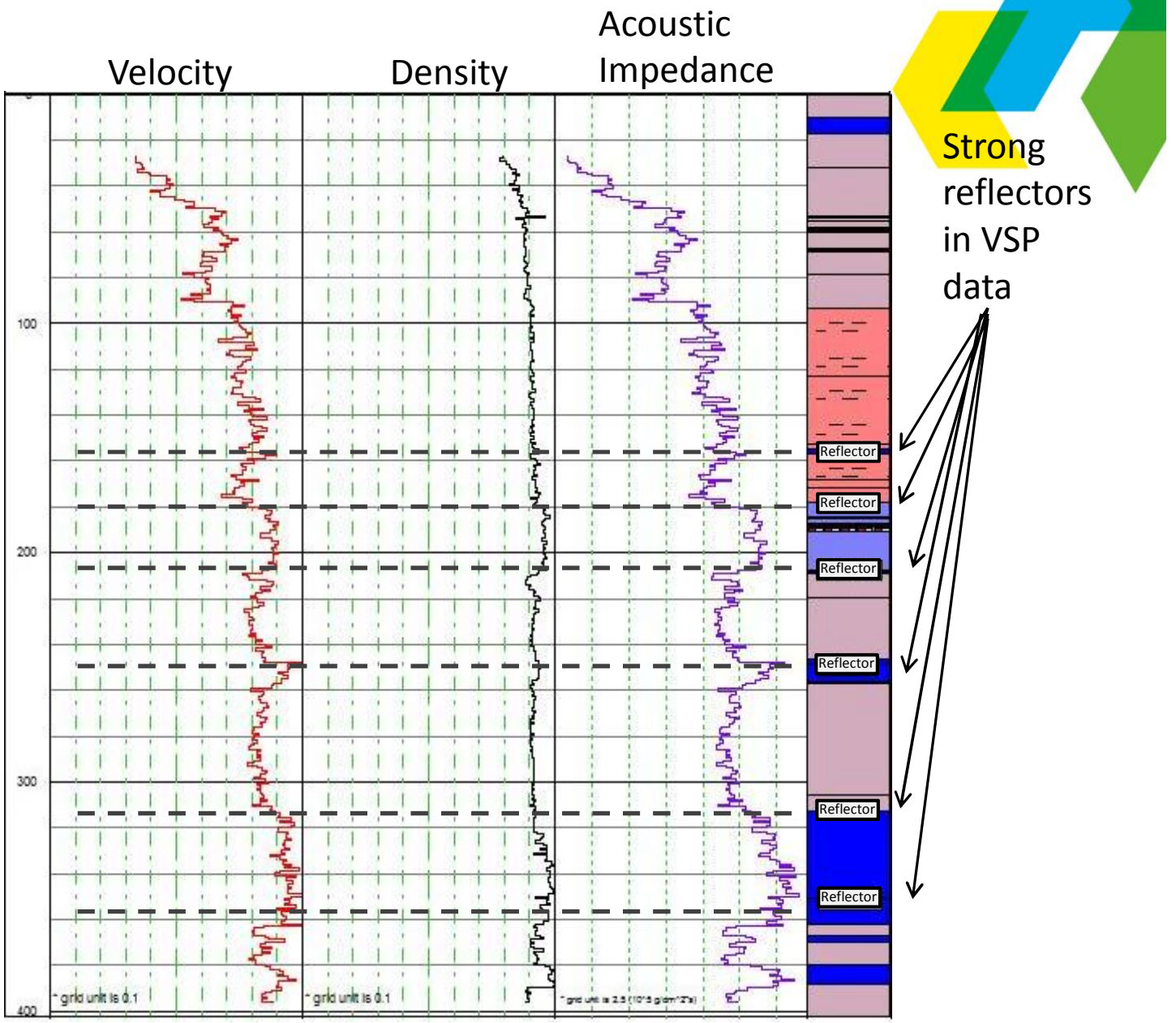


# PAULSEN'S CROSS-SECTION



G3

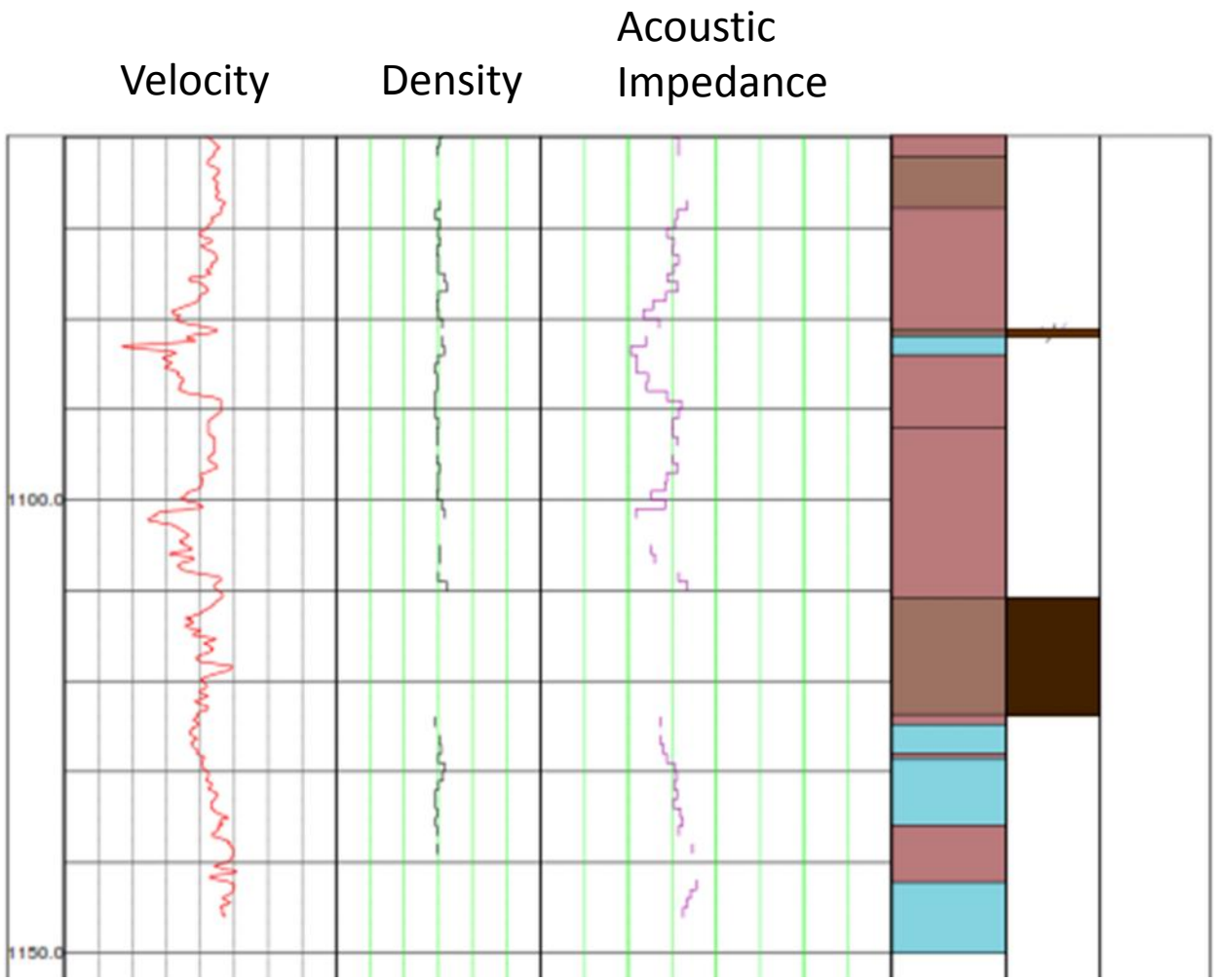
# SONIC AND DENSITY LOGS



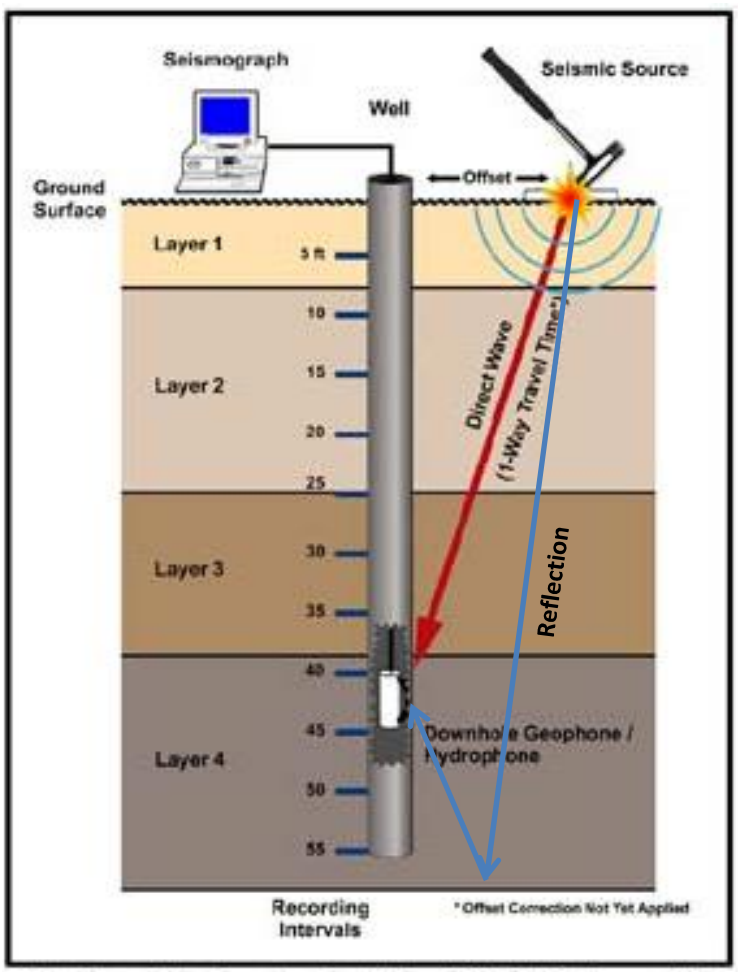
G3 pedance contrasts

Greg, 16/04/2013

# SHEAR ZONE SEISMIC LOGS



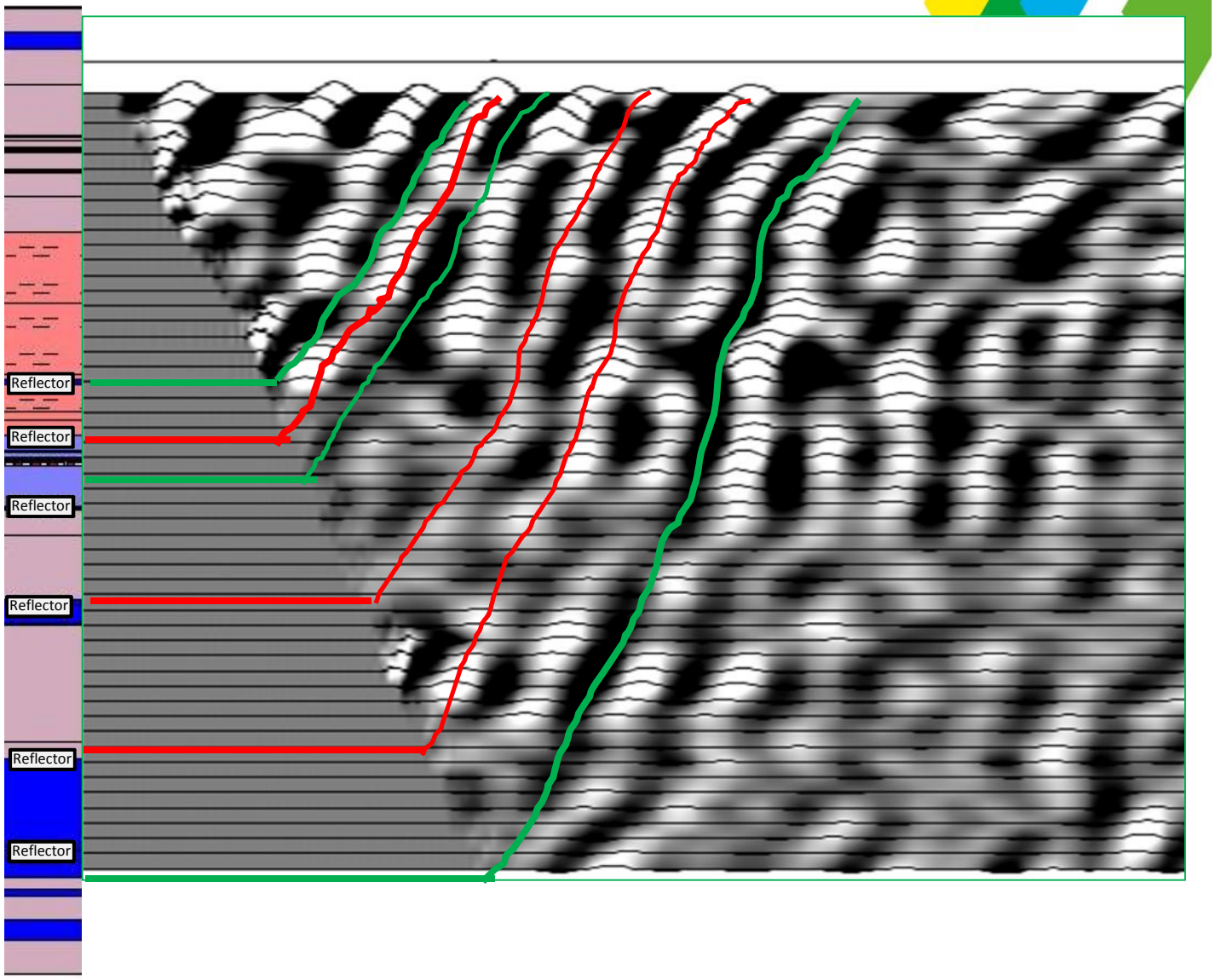
# VSP




Vertical Seismic Profile (VSP) Schematic

VSP's provide the macro-scale linkage between geological/petrophysical variations and the bulk in-situ response measured using surface seismic reflection techniques

# VSP


Reflector
Reflector
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Reflector
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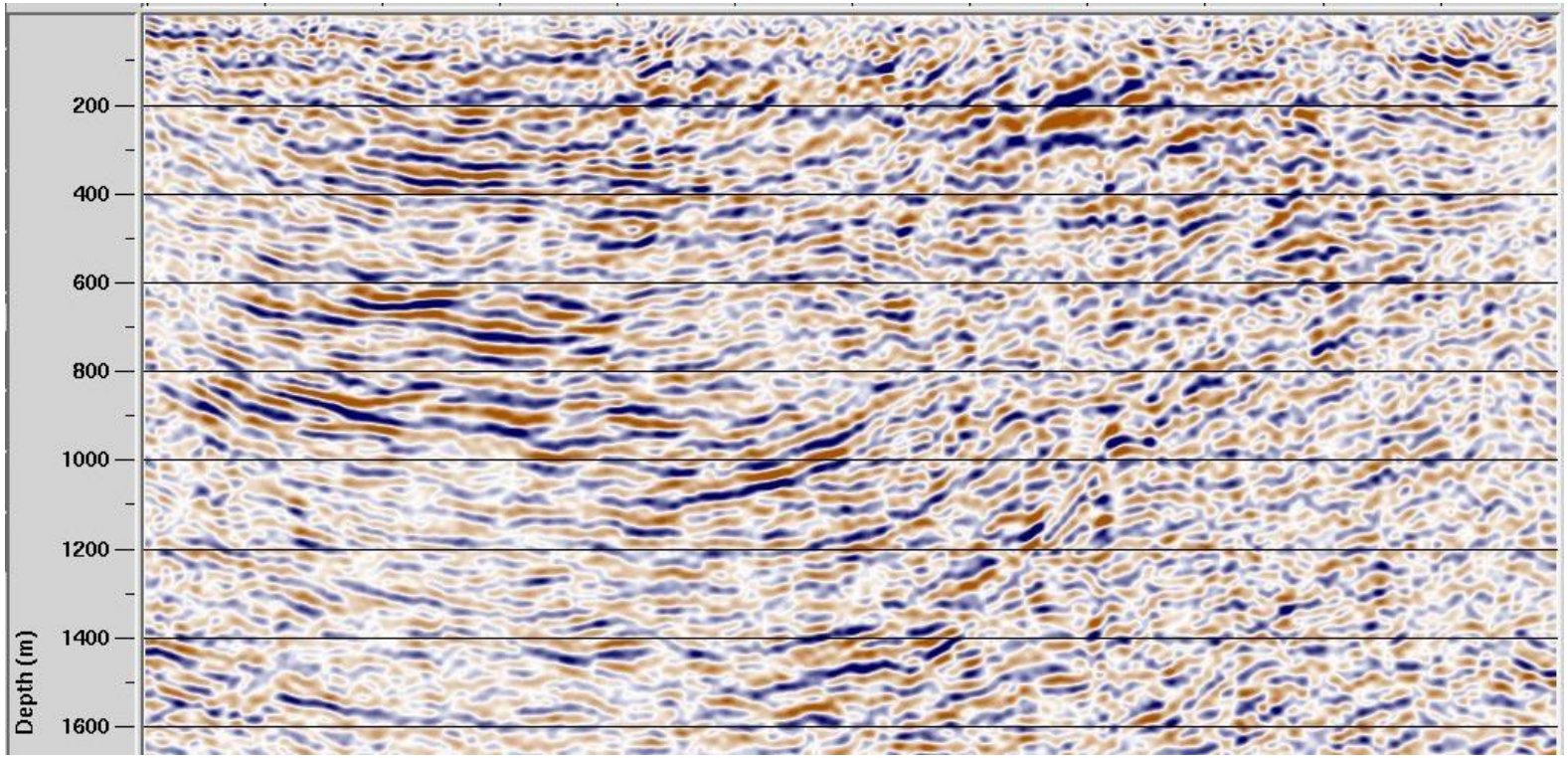
Reflector

# SEISMIC TEXTURE

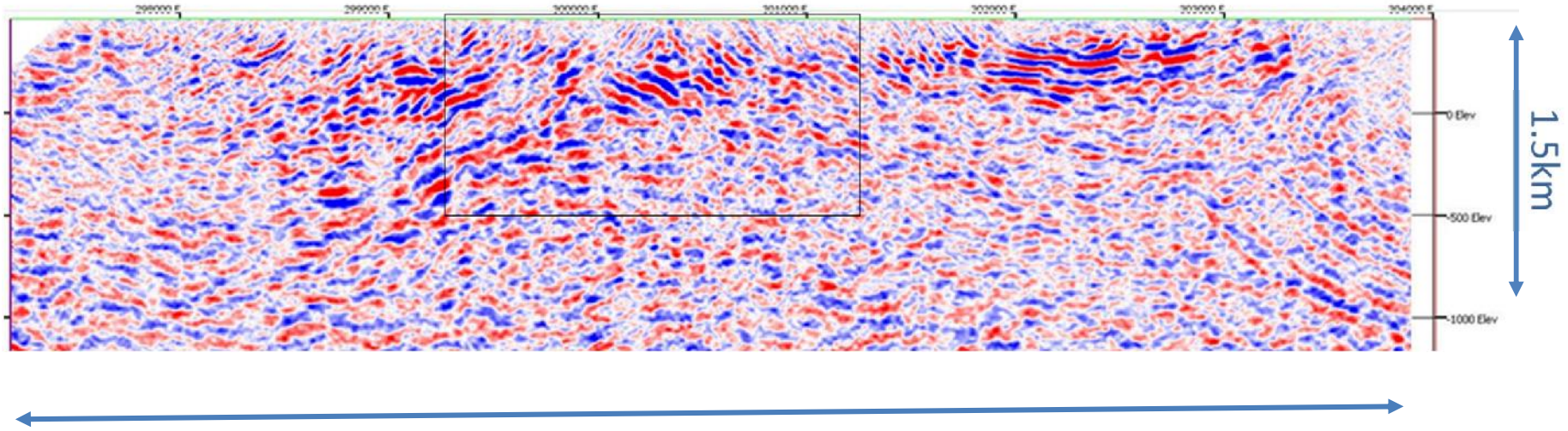



Strong semi-continuous reflections

Shear

Multiple discontinuous reflections

# CASE STUDY – BULLABULLING




**Objectives**

- *Map the mineralised shear system*
- *Generate targets at depth*

# CASE STUDY – BULLABULLING

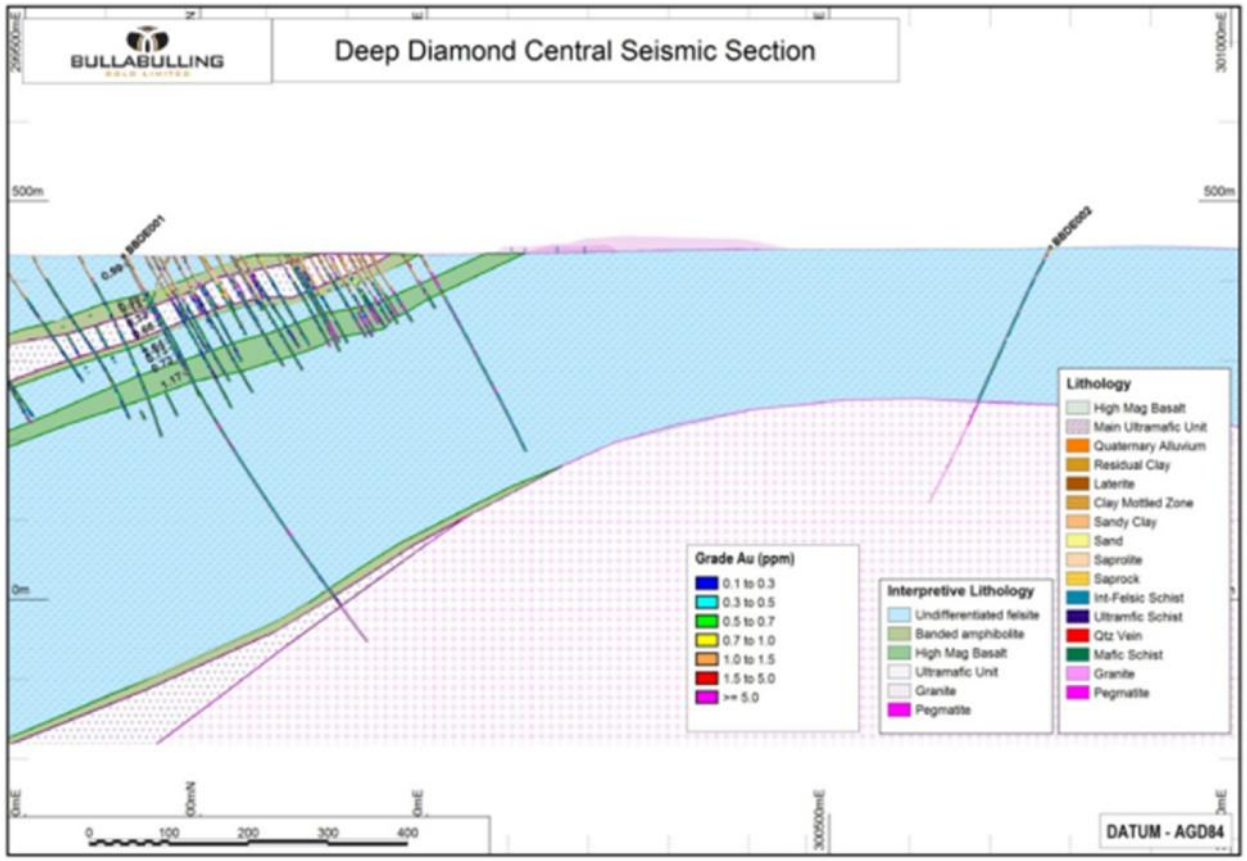
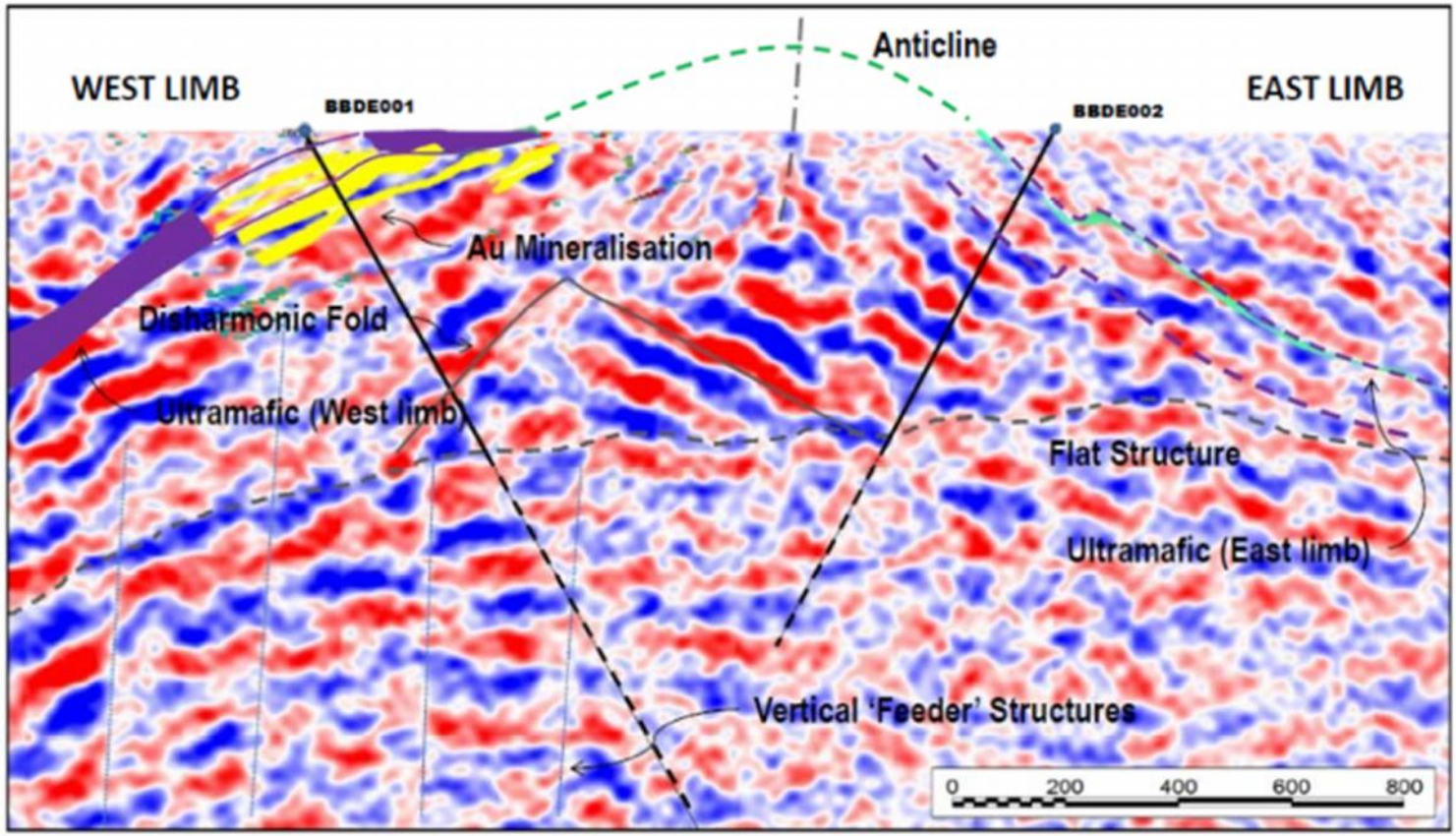



**Figure 1: Section showing lithology and mineralization on traces of BBDE001 and BBDE002 with preliminary interpretation**

# CASE STUDY – BULLABULLING



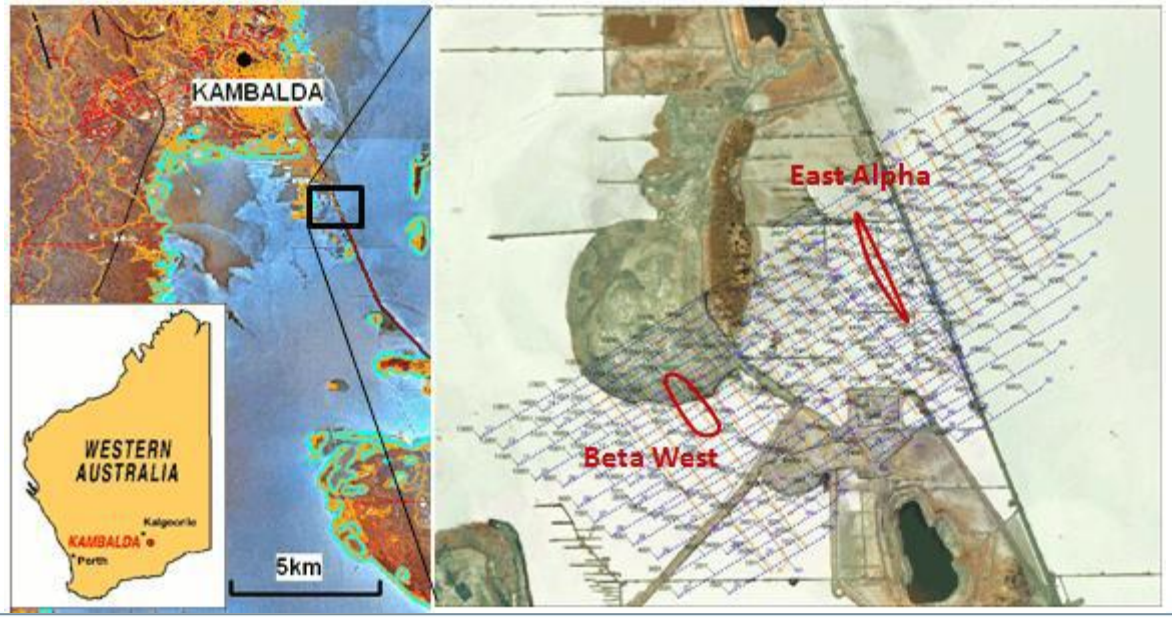

Cross-section on Seismic Line Showing Planned Drill Holes

# CASE STUDY – KAMBALDA

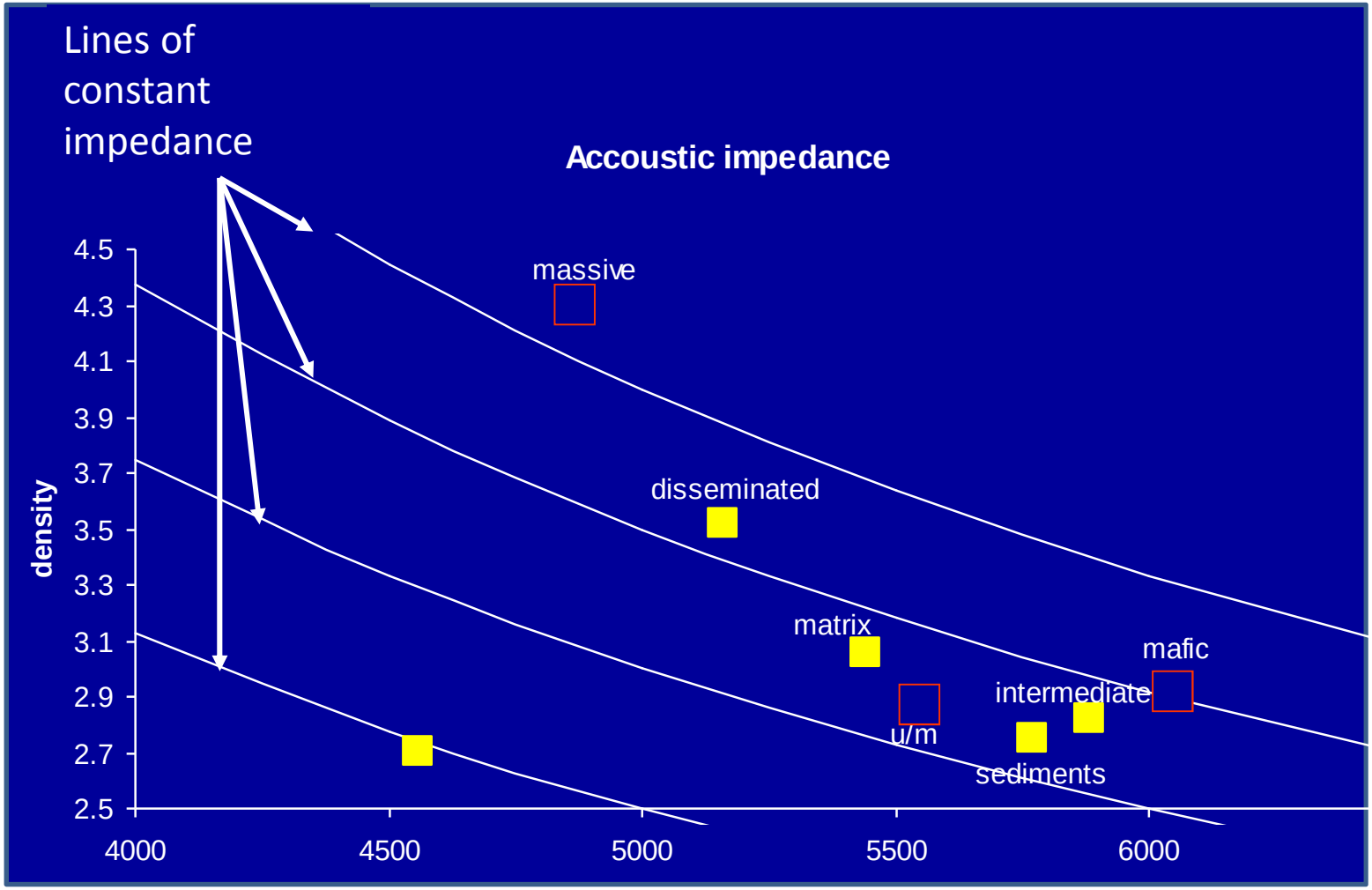
*Milovan et al 2013*

**Objectives**

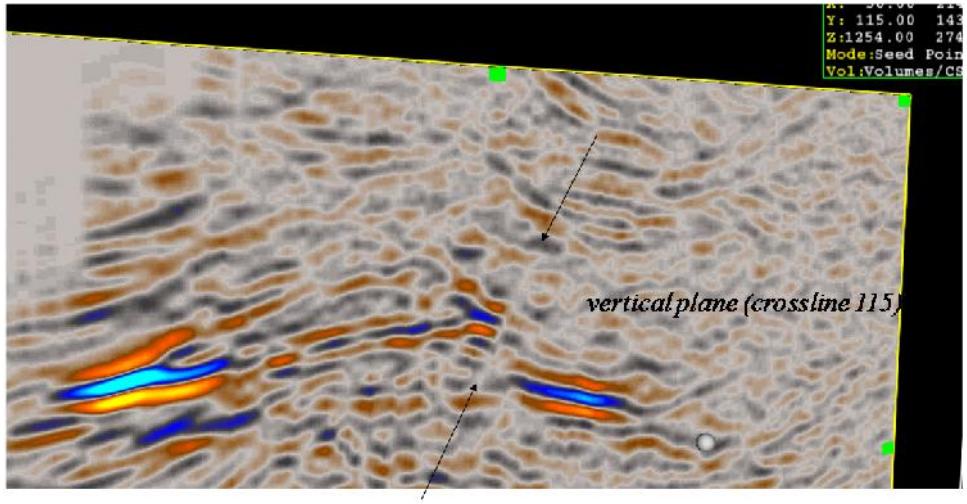
- *Map subsurface stratigraphy and structure to 1km depth*
- *Map the basalt/ultramafic contact*
- *Map structures that offset this surface*
- *Detect Mineralisation*

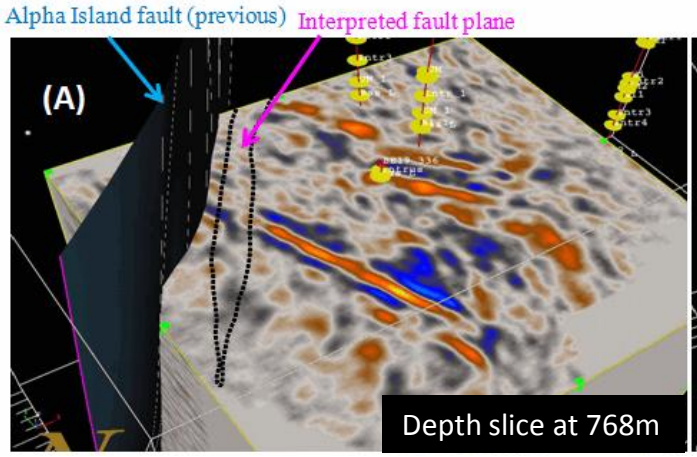


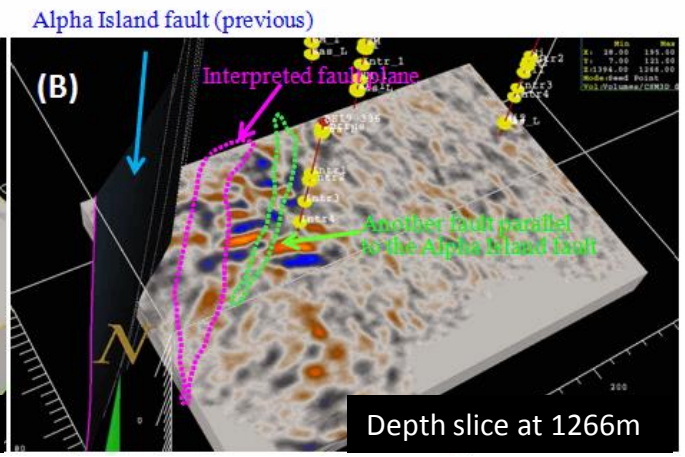
# KAMBALDA ROCK PROPERTIES



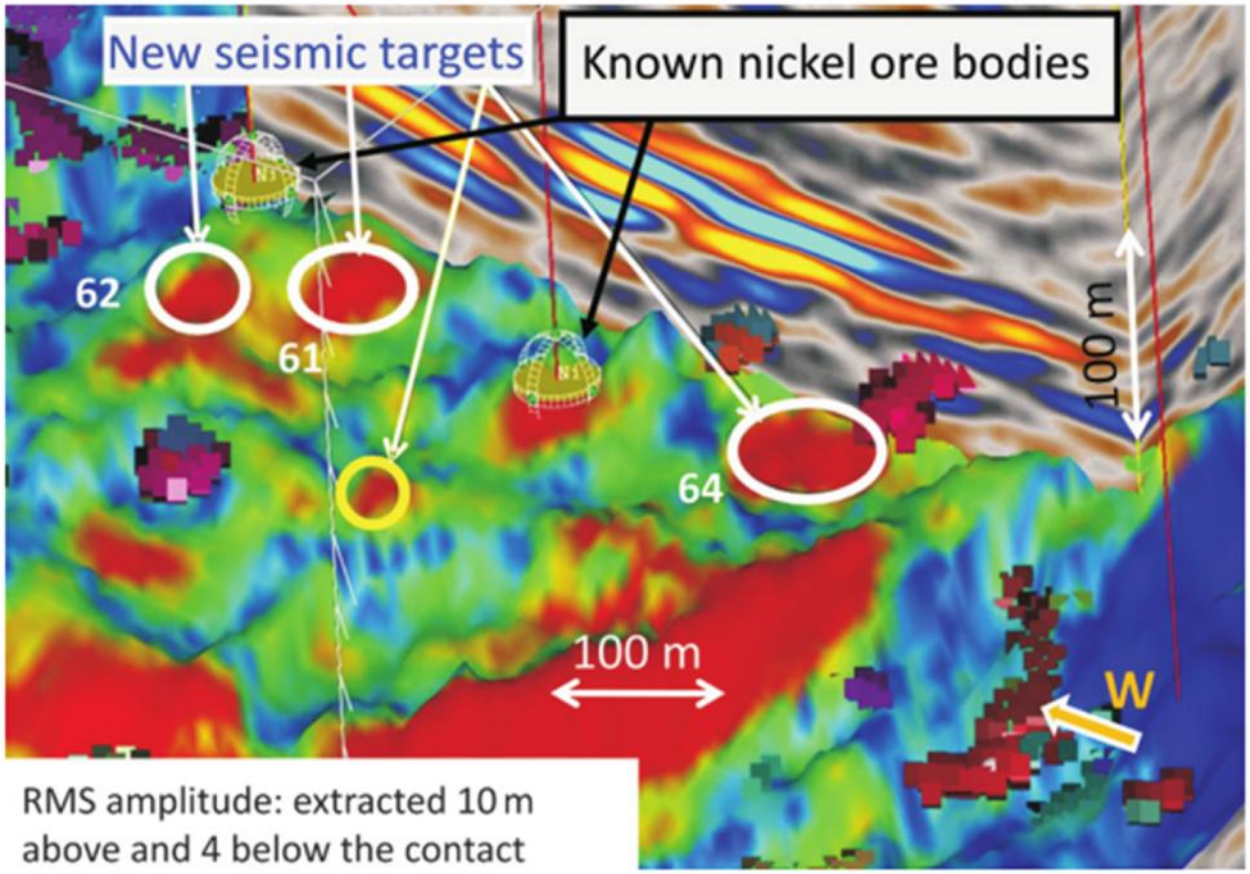
# KAMBALDA FAULTING



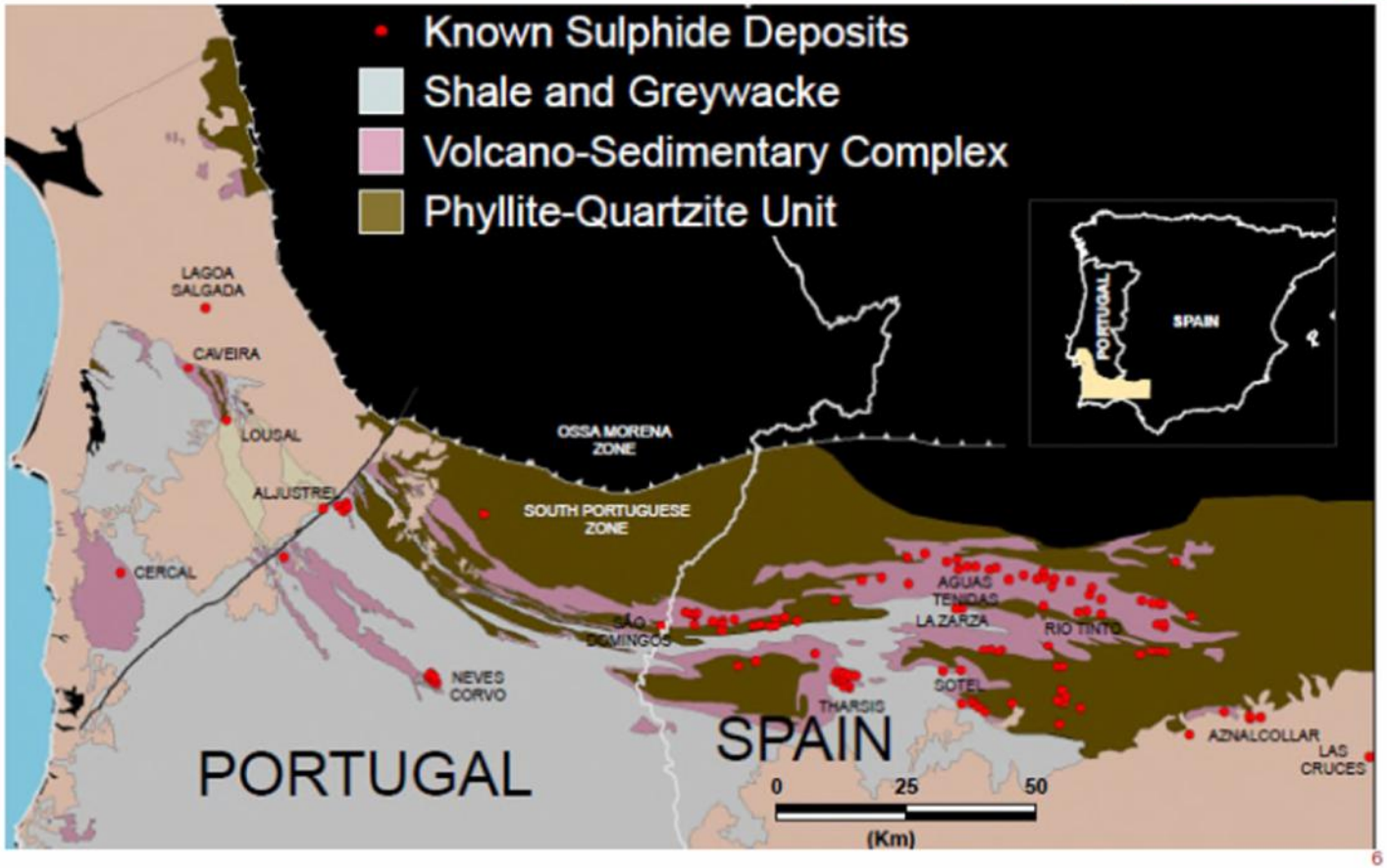



# HiSeis Data: Kambalda WA



# Regional Geology: Iberian Pyrite Belt

lundin mining



# Iberian Pyrite Belt: Structure & Stratigraphy

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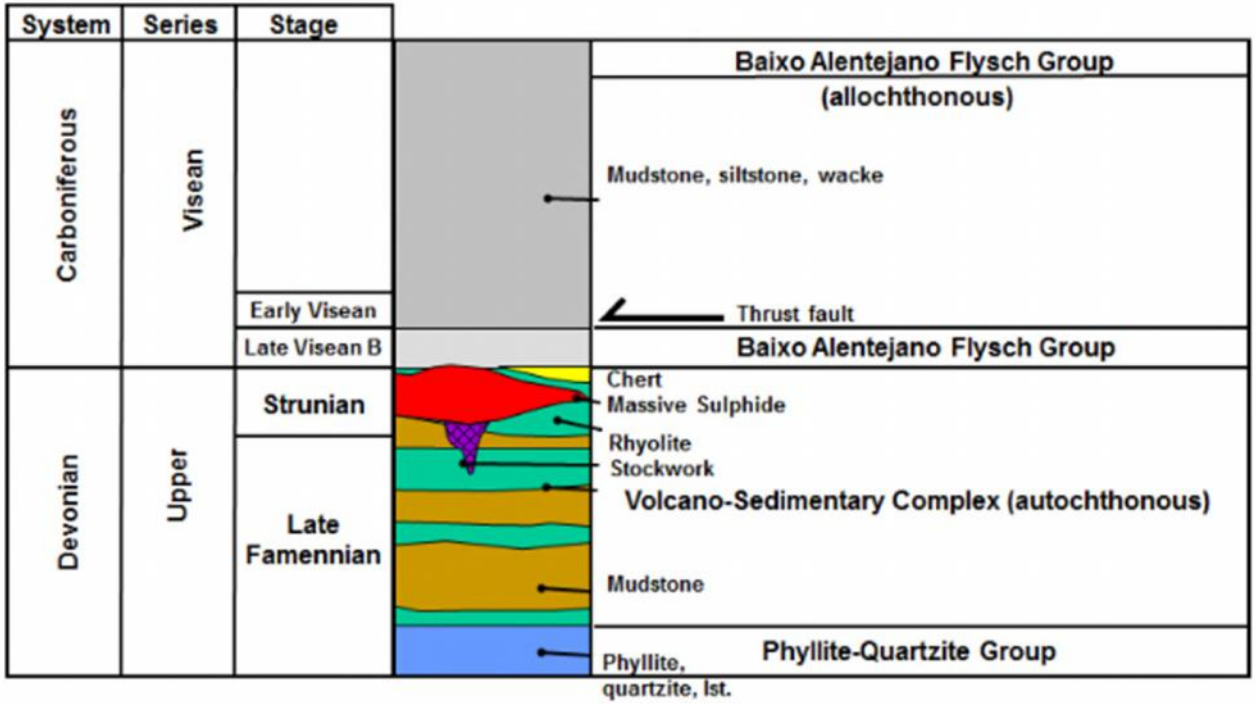




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# Neves-Corvo: Big Massive Sulphide Deposits

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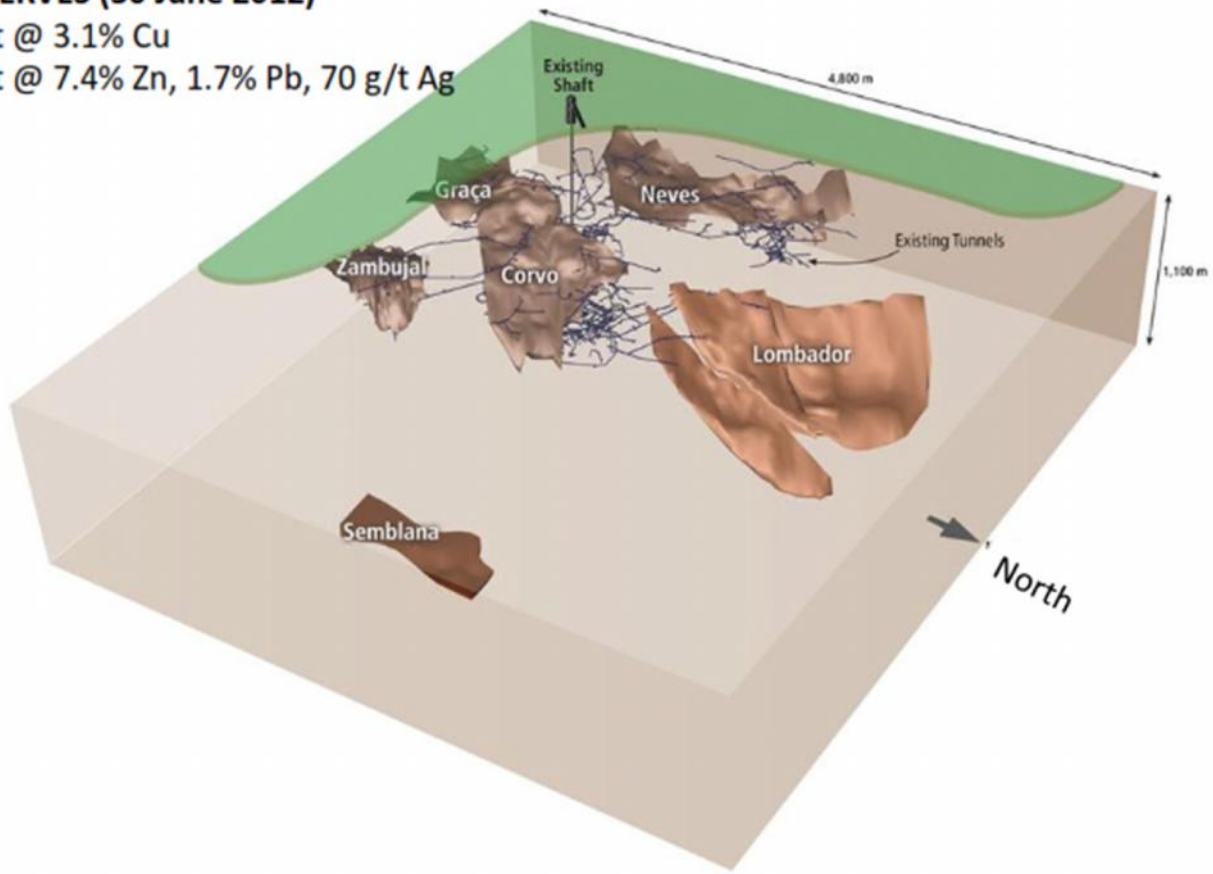
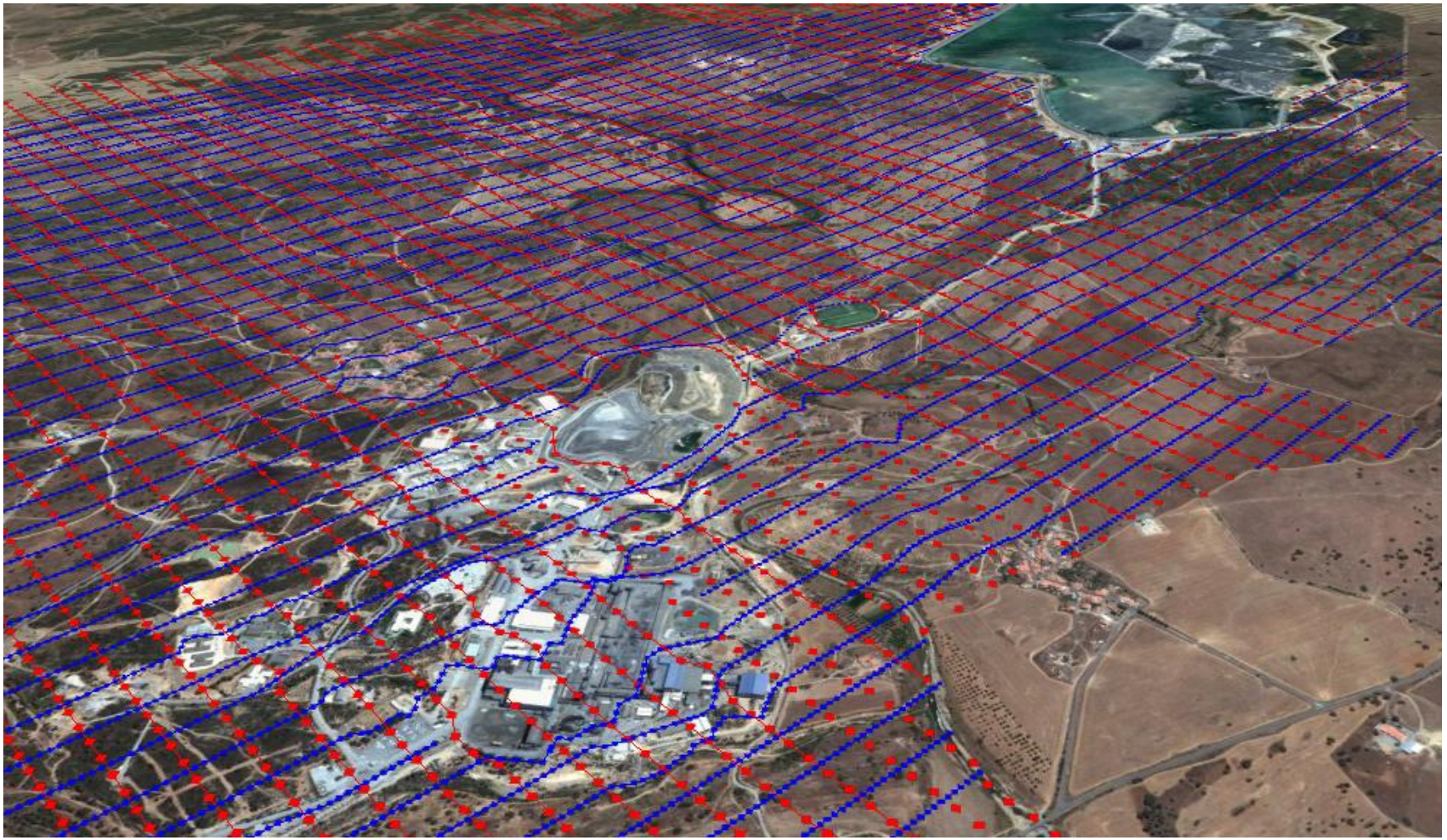
**2P RESERVES (30 June 2012)**

24.1Mt @ 3.1% Cu

22.7Mt @ 7.4% Zn, 1.7% Pb, 70 g/t Ag

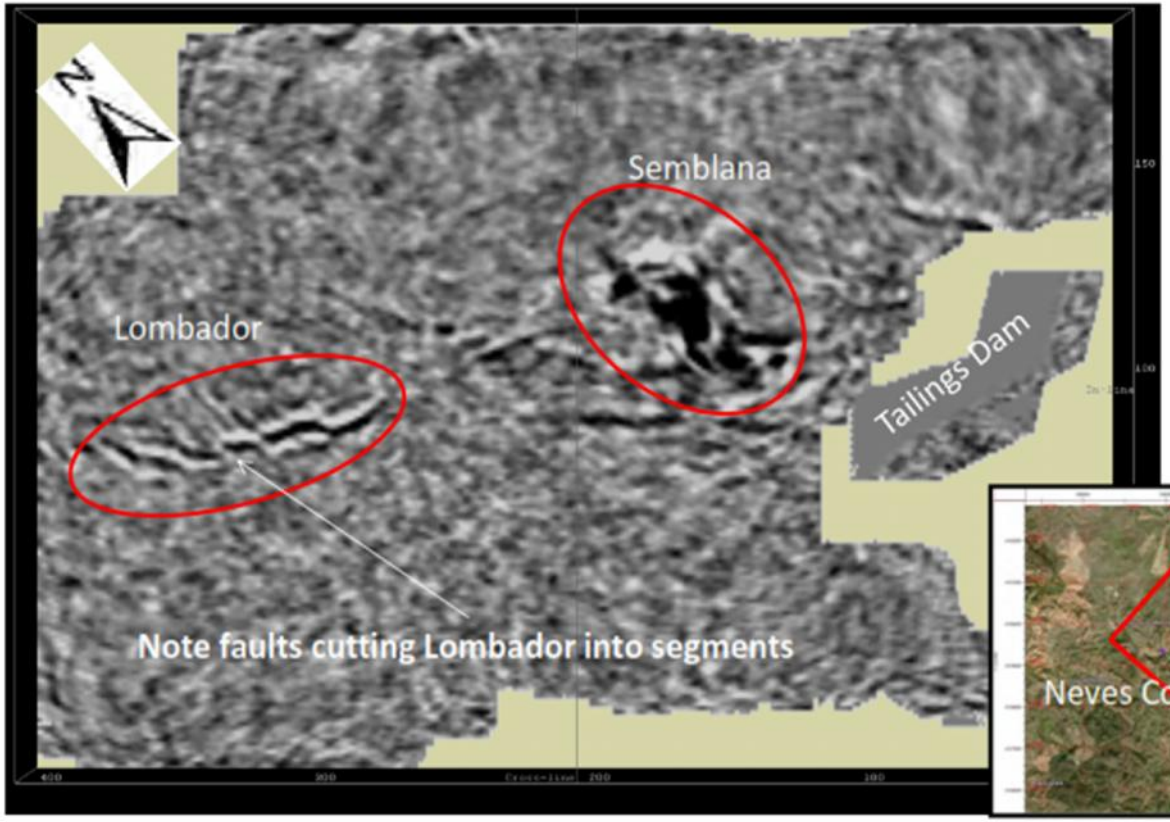


# 3D SURVEY GRID OVER MINE



# 3D Seismic Survey Depth Slice at 894 m

lundin mining




High Resolution
Rx 90 x 15m
Tx 90 x 45

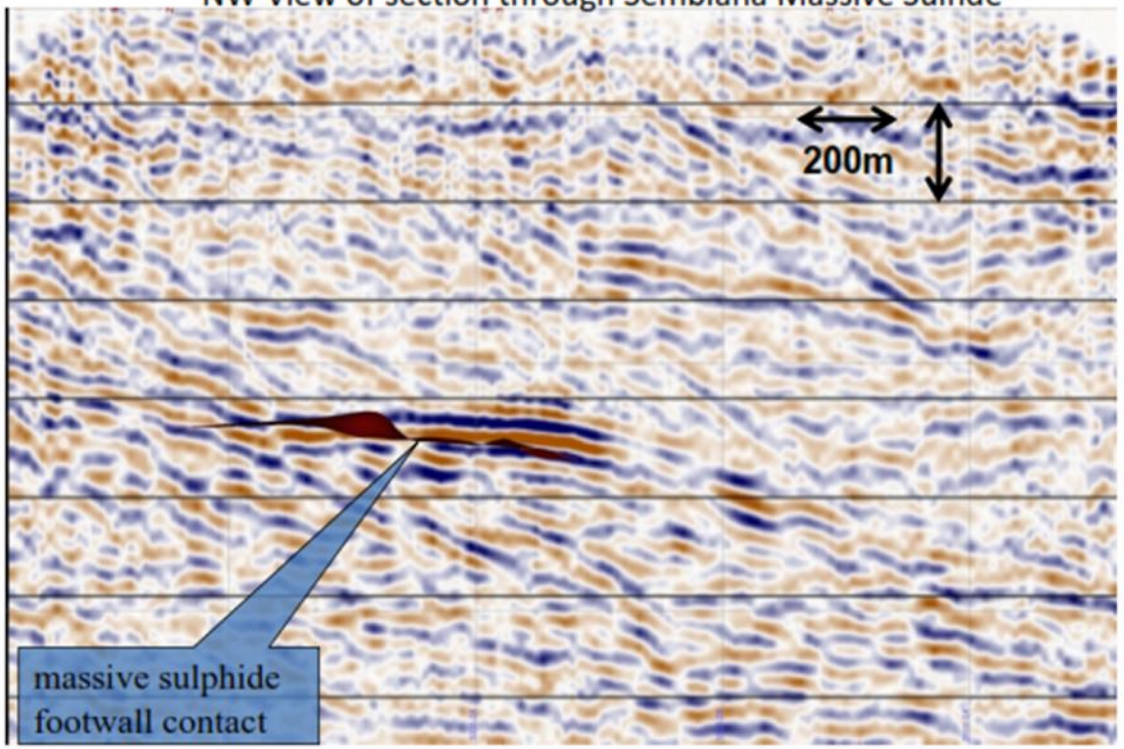
Survey Block
6.4 x 4.6 km

# 3D Seismic Survey at Neves-Corvo – Section

lundin mining

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

NW View of section through Semblana Massive Sulfide



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# 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


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

- Detect structures & alteration.
- Directly detect some mineralisation styles
- Cost competitive @ $250K/km$^2$.
- Rapid results.
- Low environmental impact.
- Faster 3D targeting of drilling

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# Acknowledgements


**Consolidated Minerals Ltd**
**Bullabulling Gold Ltd**
**Northern Star Resources Ltd**
**Lundin Mining**
**MMG**

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