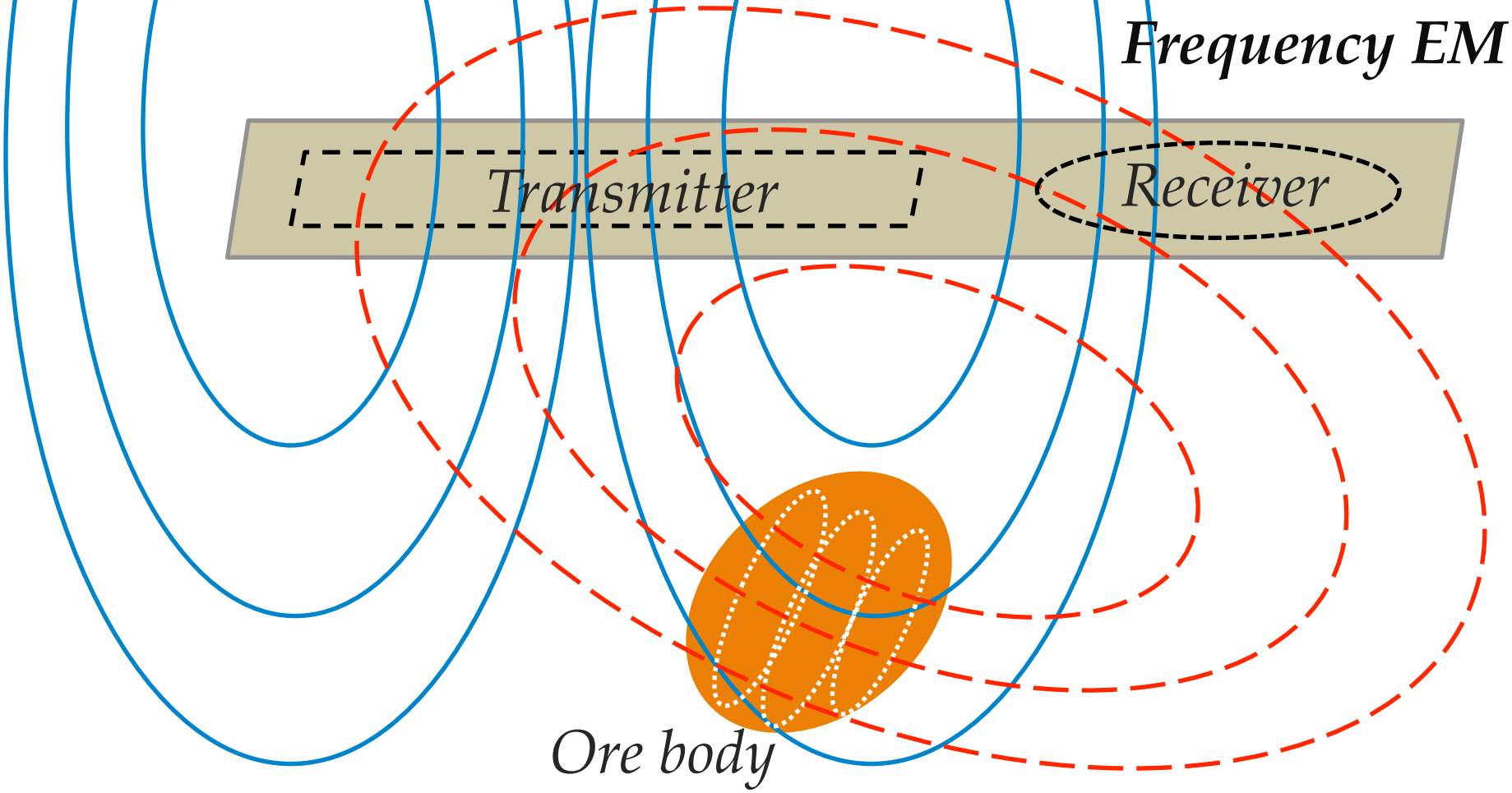
Electromagnetic Modelling

On-time EM
Or
Frequency EM



Bruce McMonnies

S-IMEW – Geophysics Day, Tuesday May 7th, 2019

LAMONTAGNE GEOPHYSICS LTD
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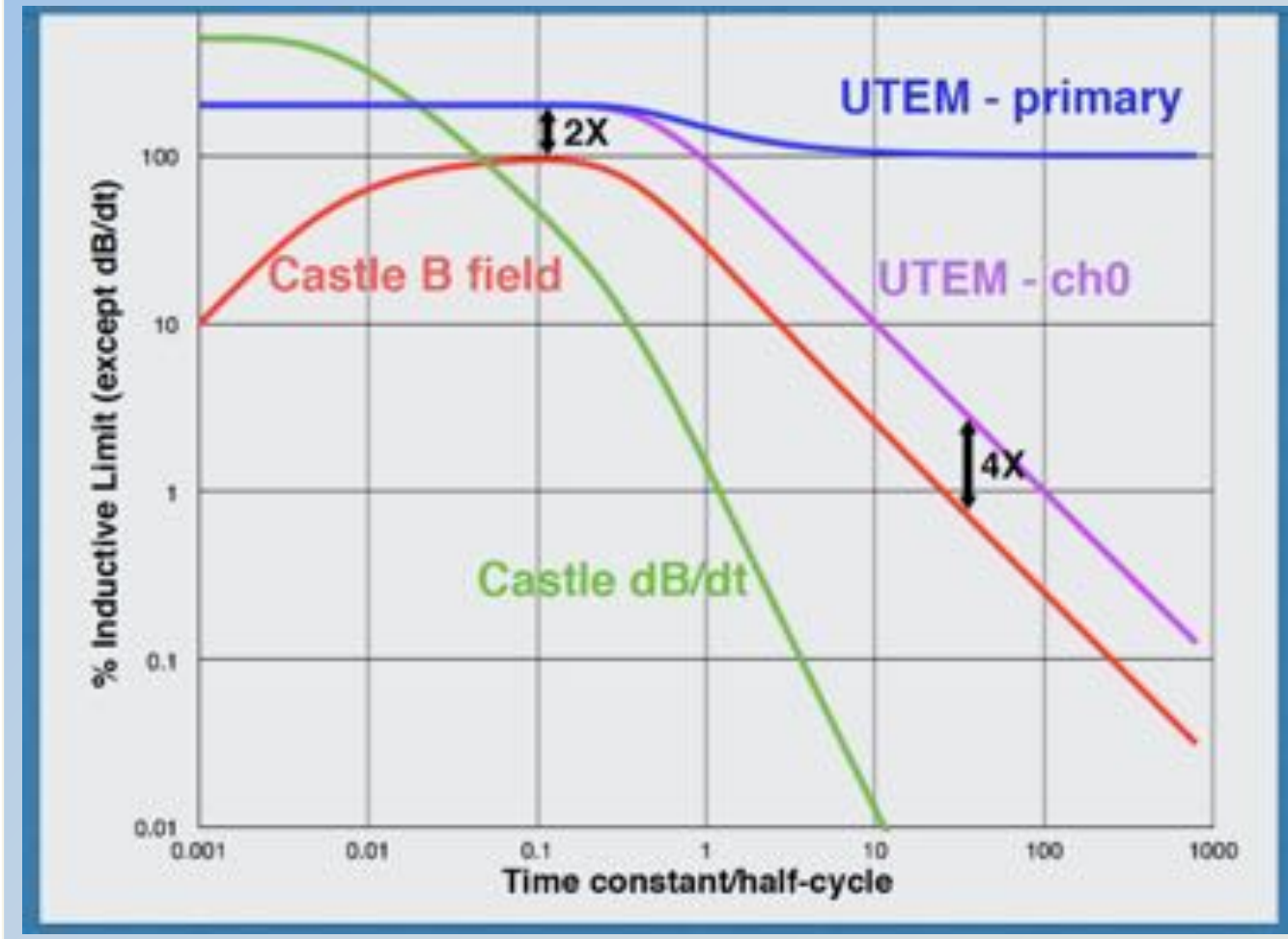
Outline

- **UTEM explanation**

- **What is EM modelling? Interpretation!!**

  Commonly referred to as computational Electro-Magnetics is the process of modelling EM fields with physical objects and the environment. Data normally displayed in profile with qualitative interpretation matching type curves, gridding and imaging with CDIs.

- **Some case studies** - Nickel Rim South, Levack Footwall, Victoria and the Voisey's Bay Ovoid



On-time vs Off-time

CONDITIONS

Exponential decays

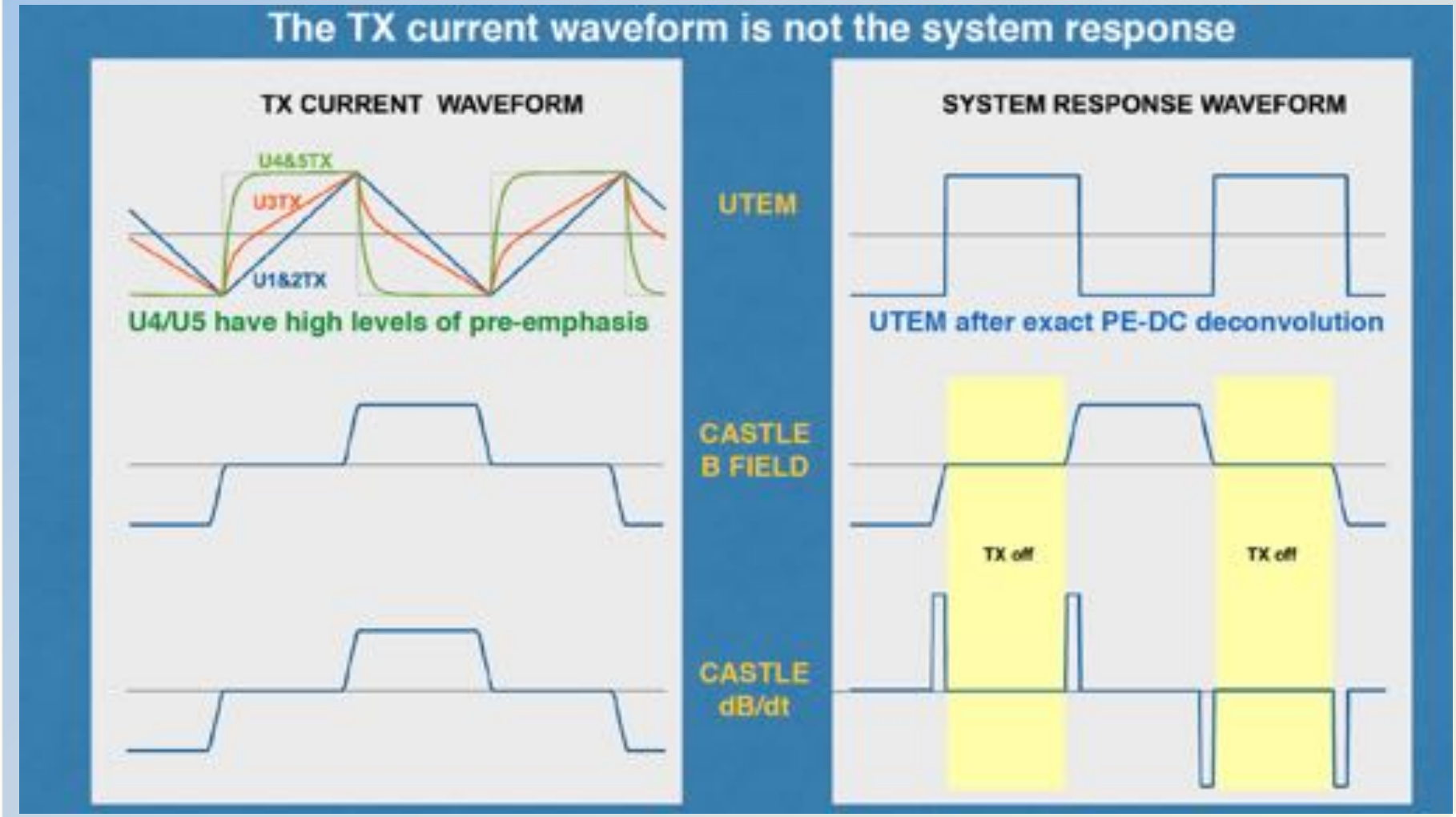
Same base frequency

Same TX current

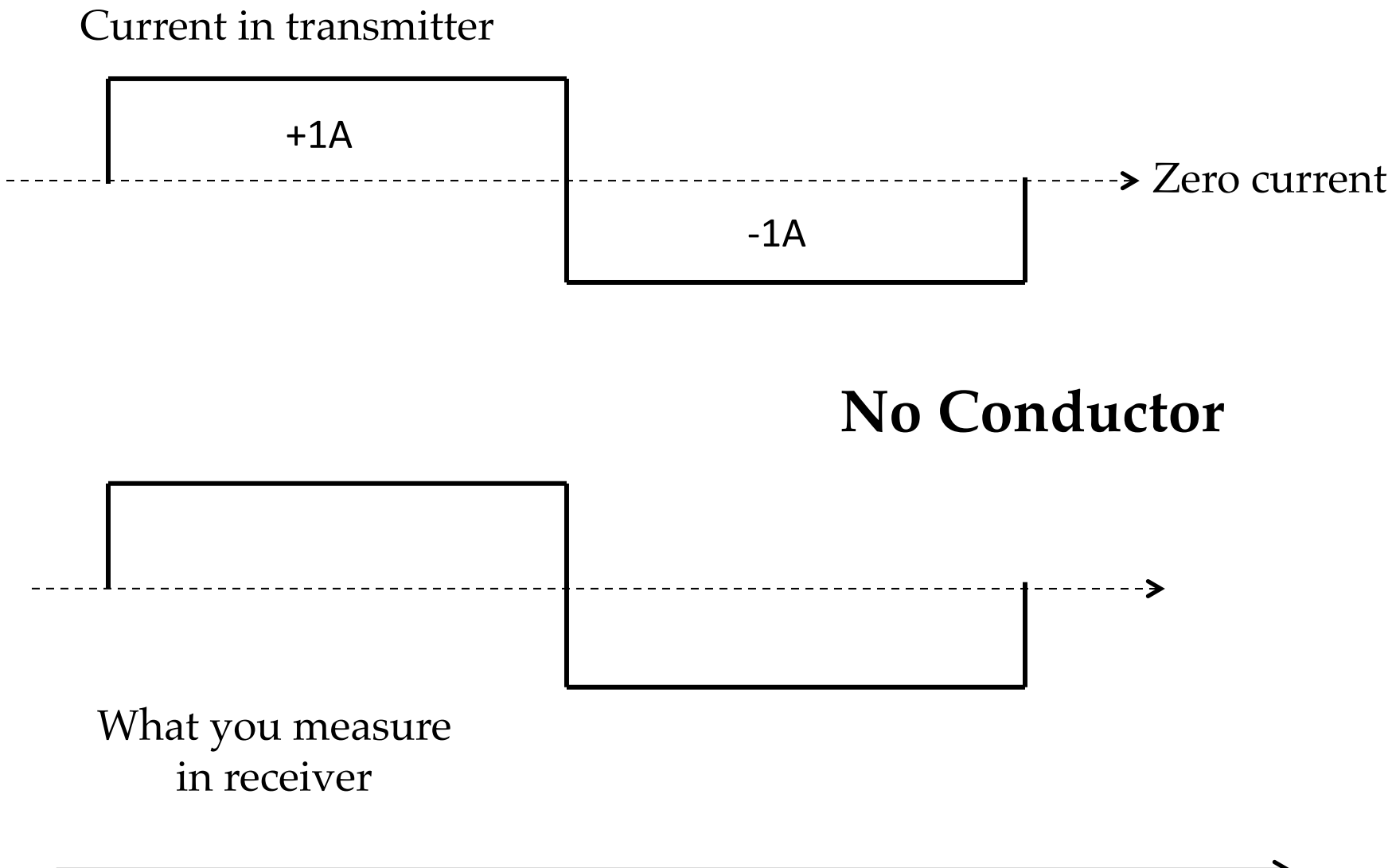
Castle waveform:
ramp time/HC = 0.01
off-time sampling

Inductive limit applies for UTEM and B field only

The TX current waveform is not the system response



Simplest form of modelling



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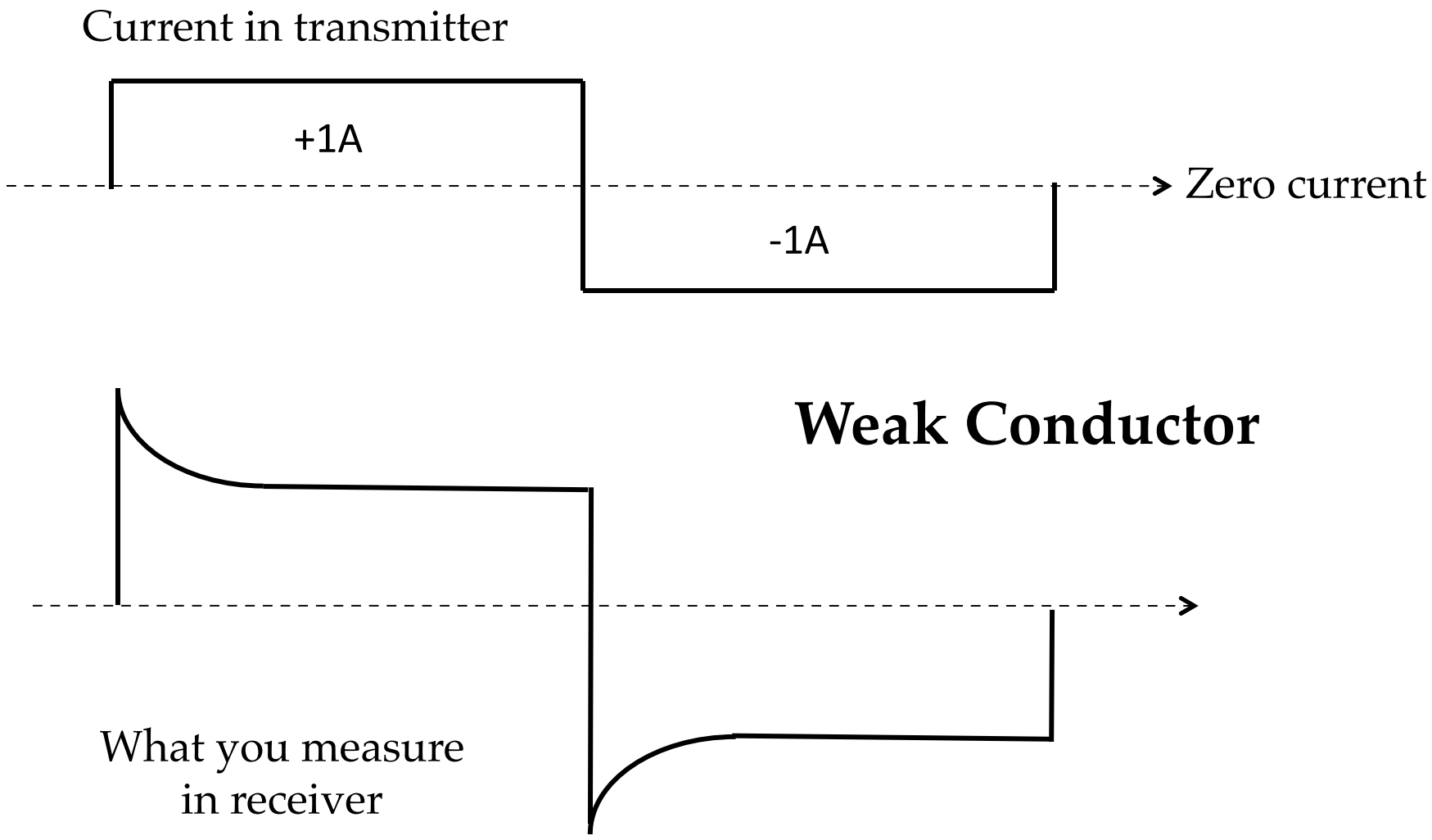

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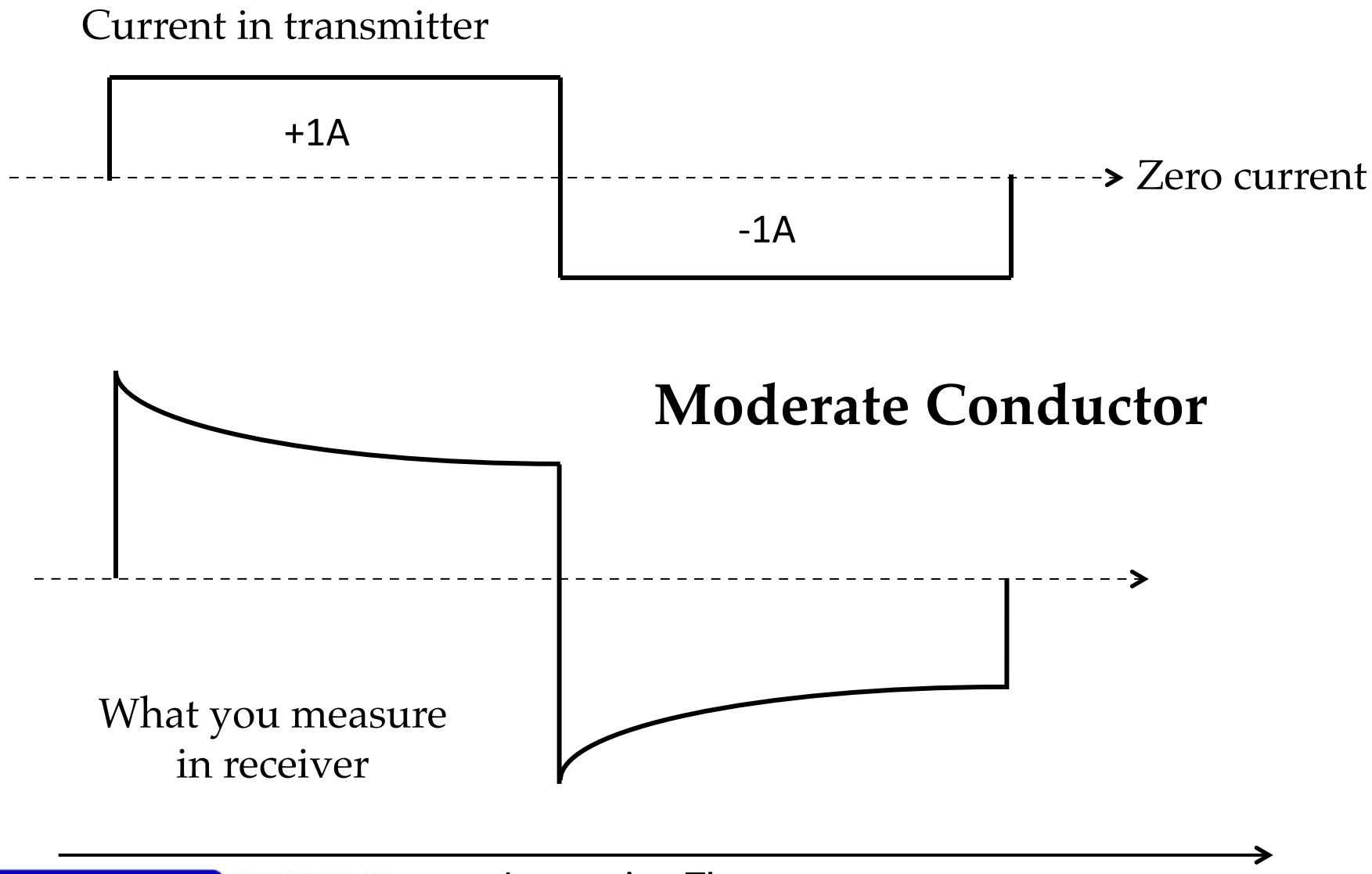
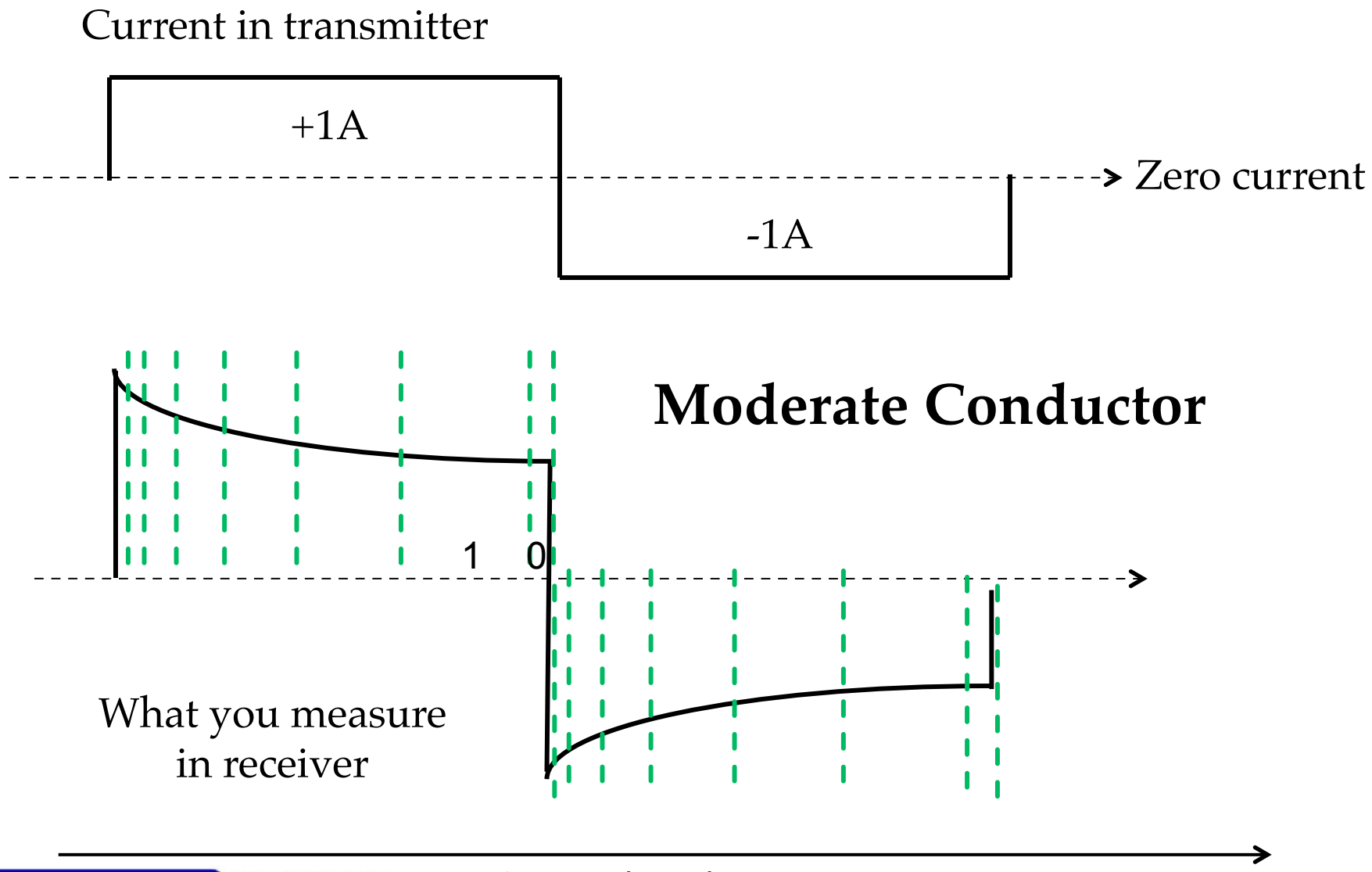


Note 'time-channels'



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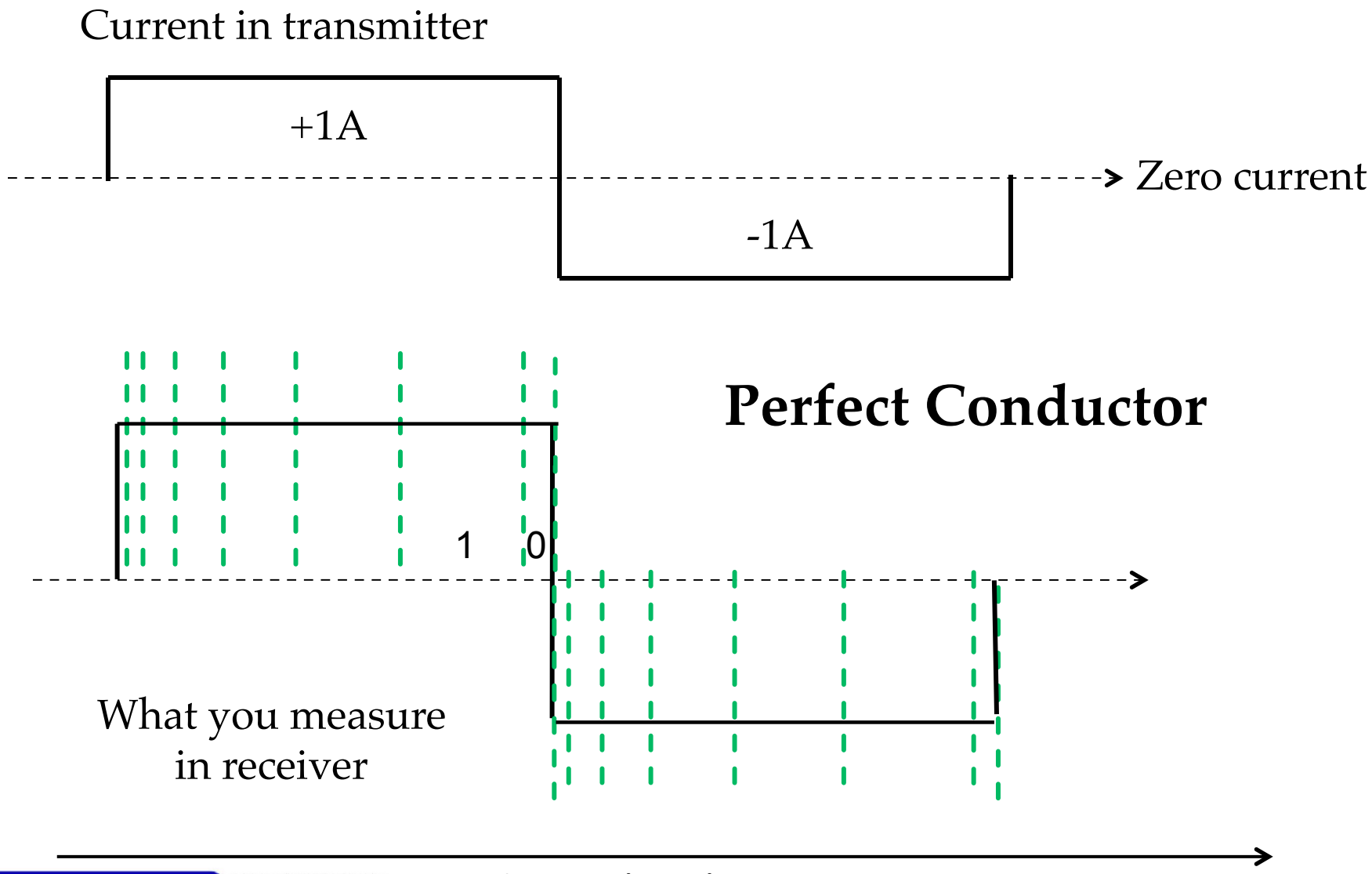
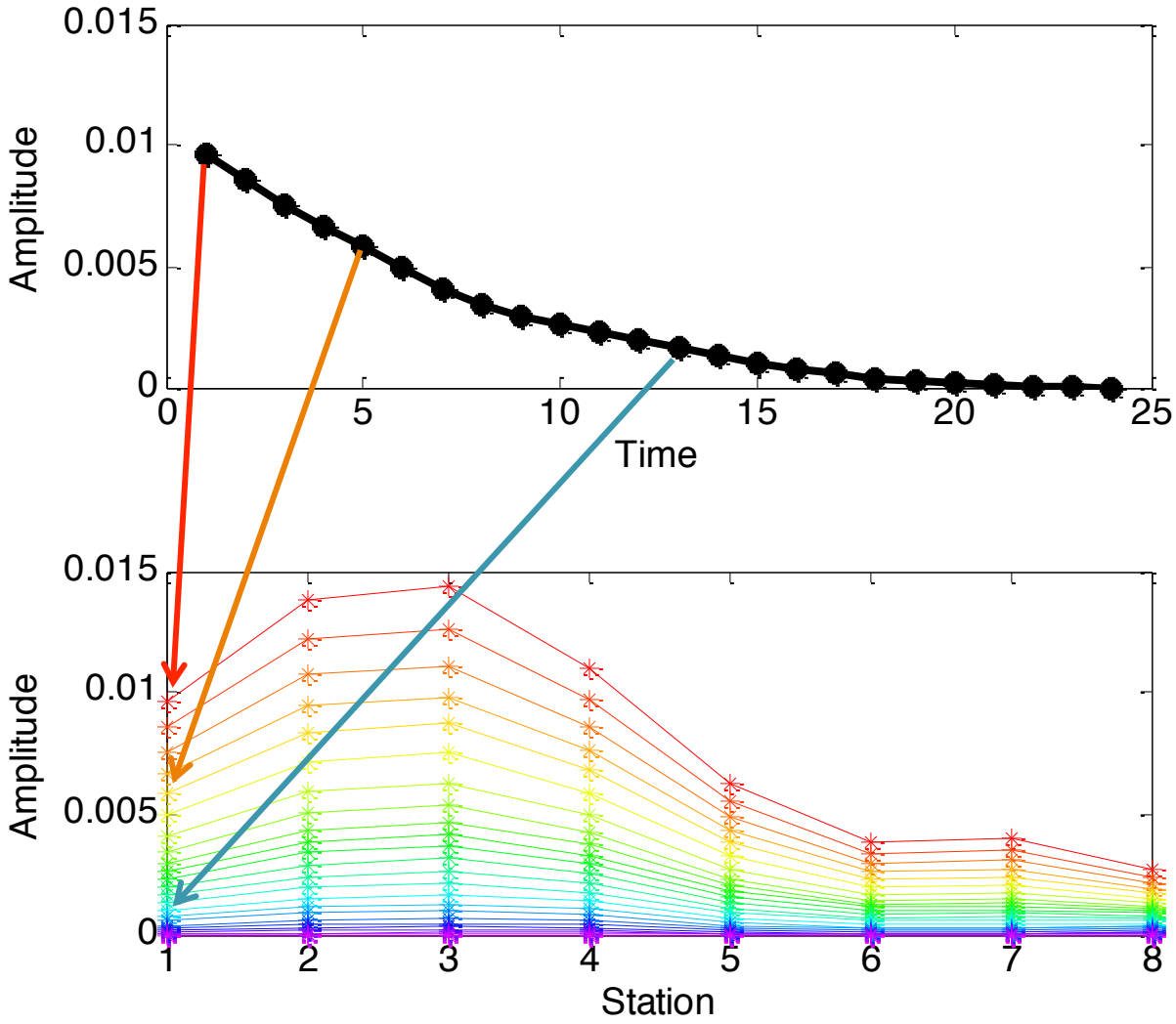
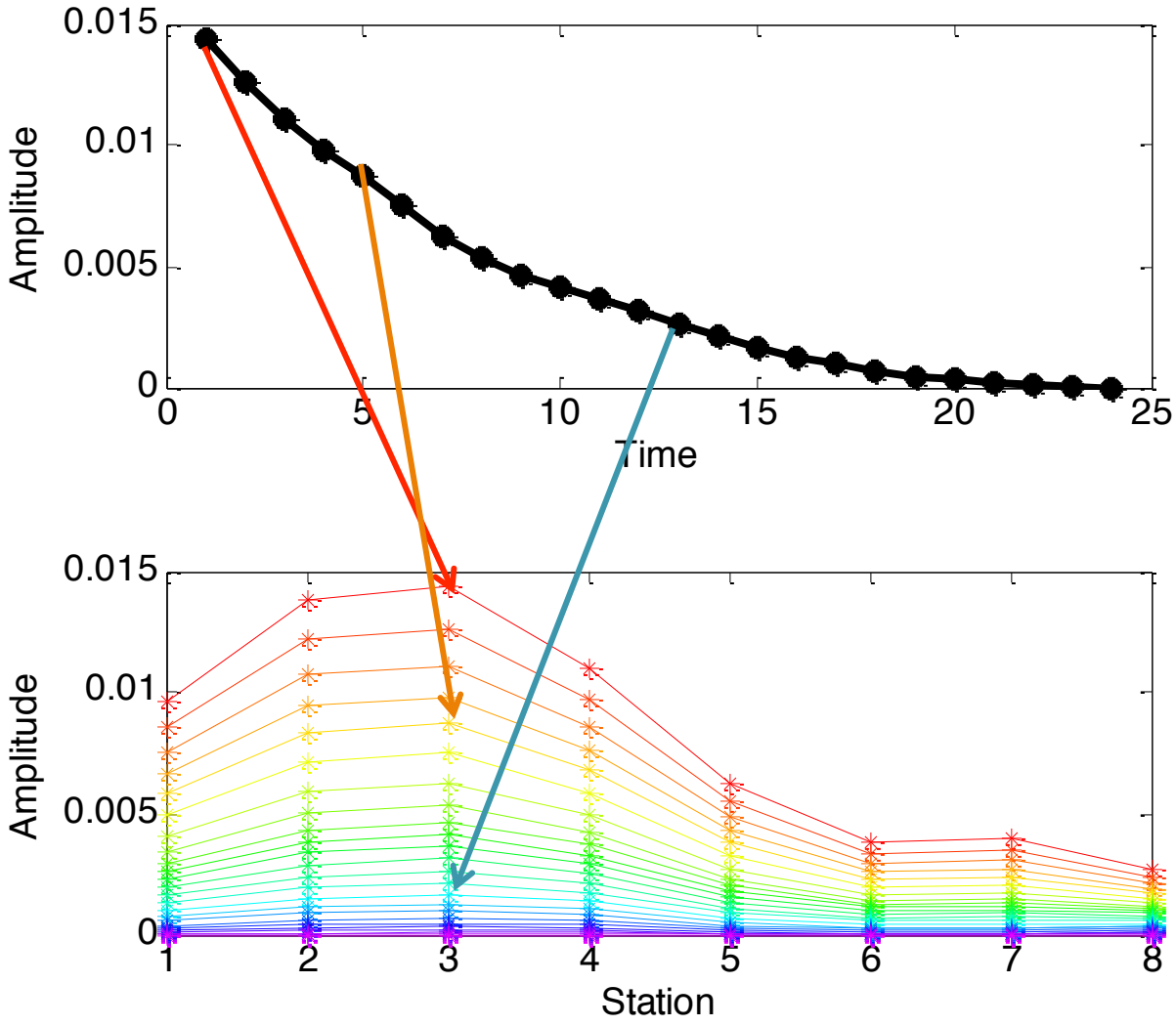


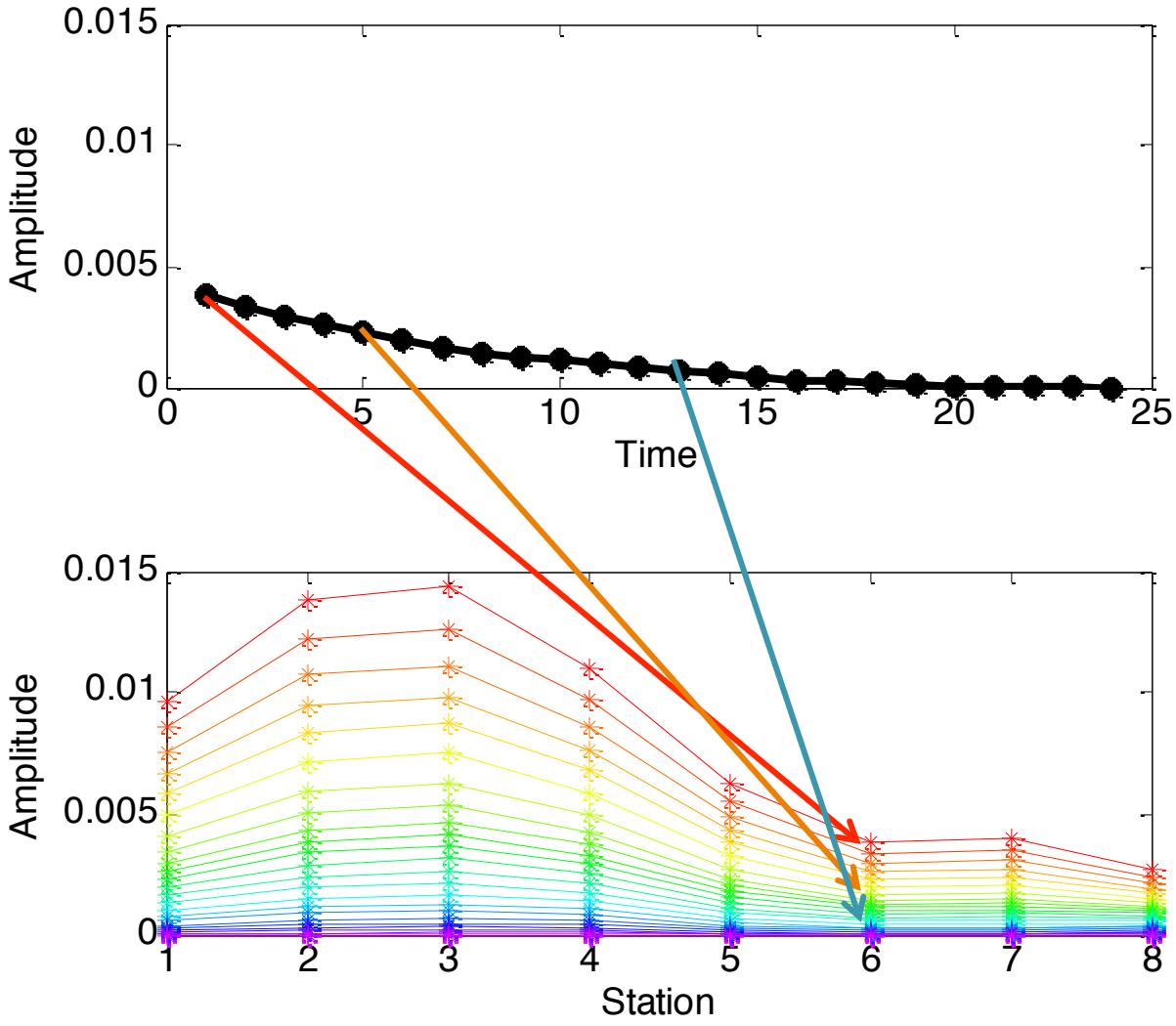
Decay curve versus Profile



Decay curve versus Profile



Decay curve versus Profile



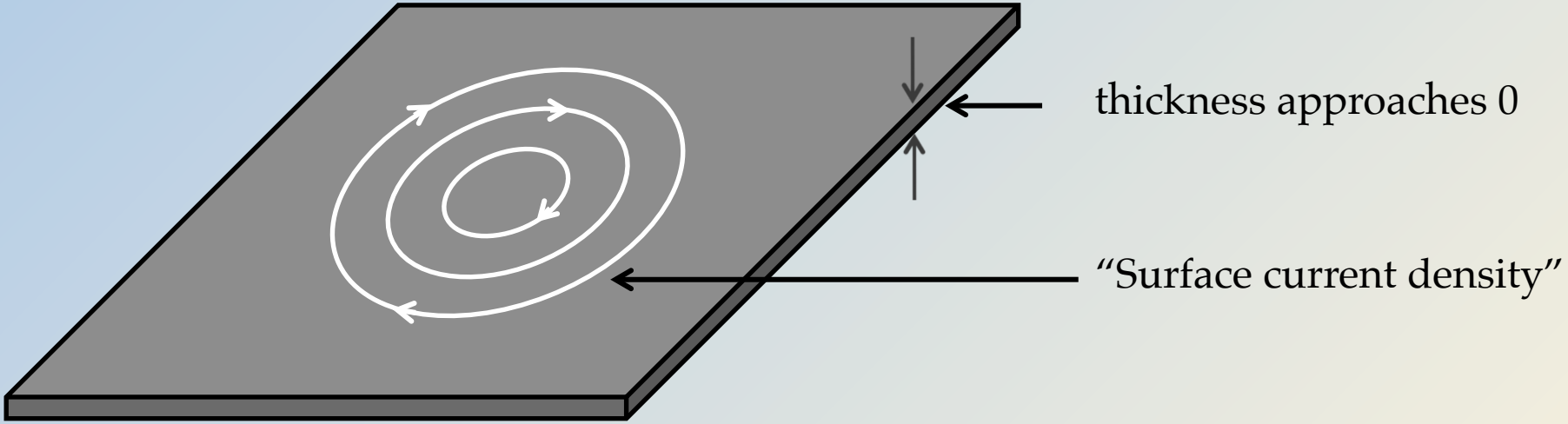
Station 6

Thin sheet approximation

Simplify when the geology allows it.

The thin sheet approximation:

- All current is constrained to flow in a sheet that is inductively thin.



Thin sheet approximation

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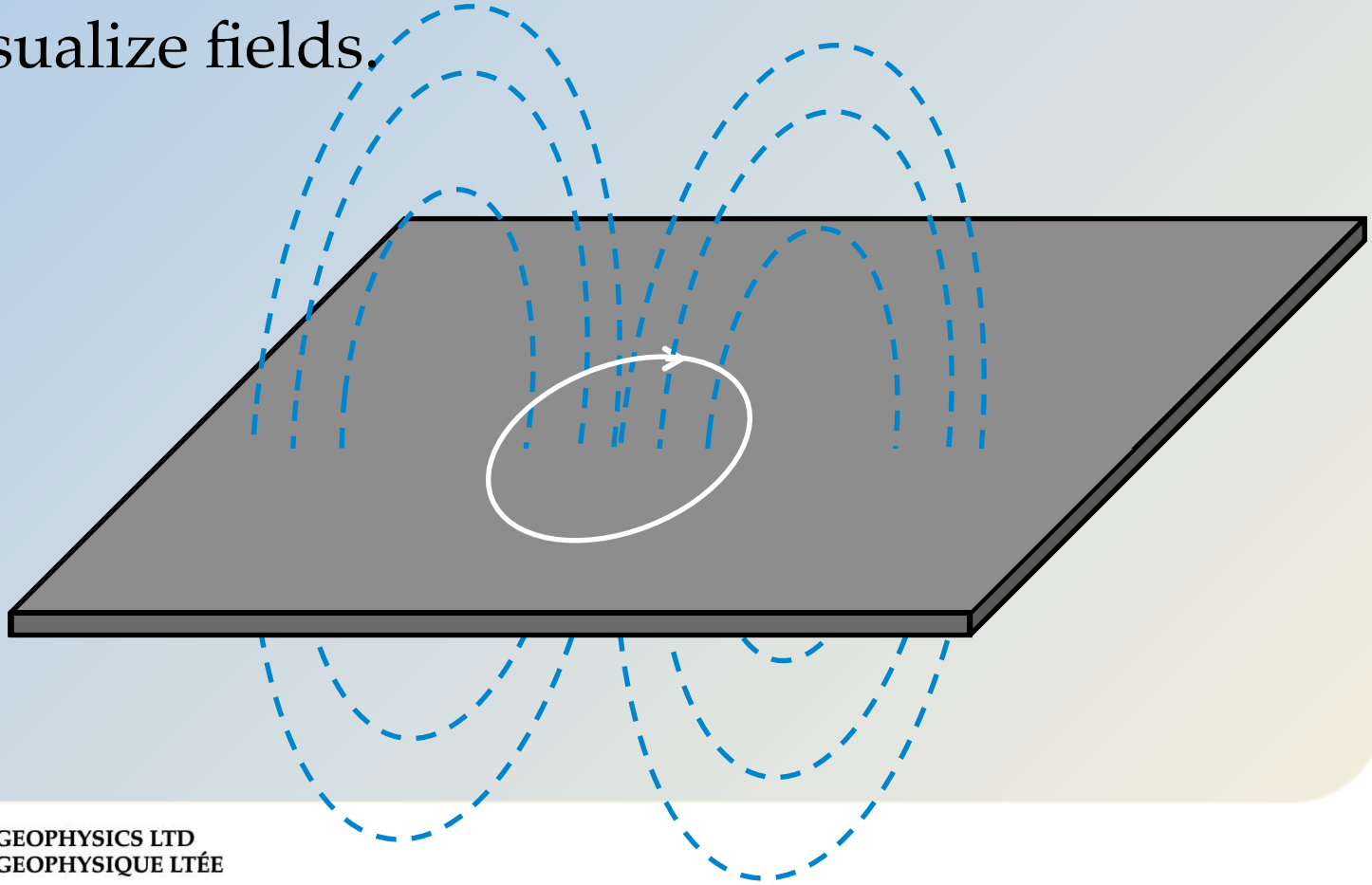
The thin sheet approximation:

- Easy to visualize fields.



Thin sheet approximation

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The thin sheet approximation:

- Many mineral deposits can be approximated as thin sheets.

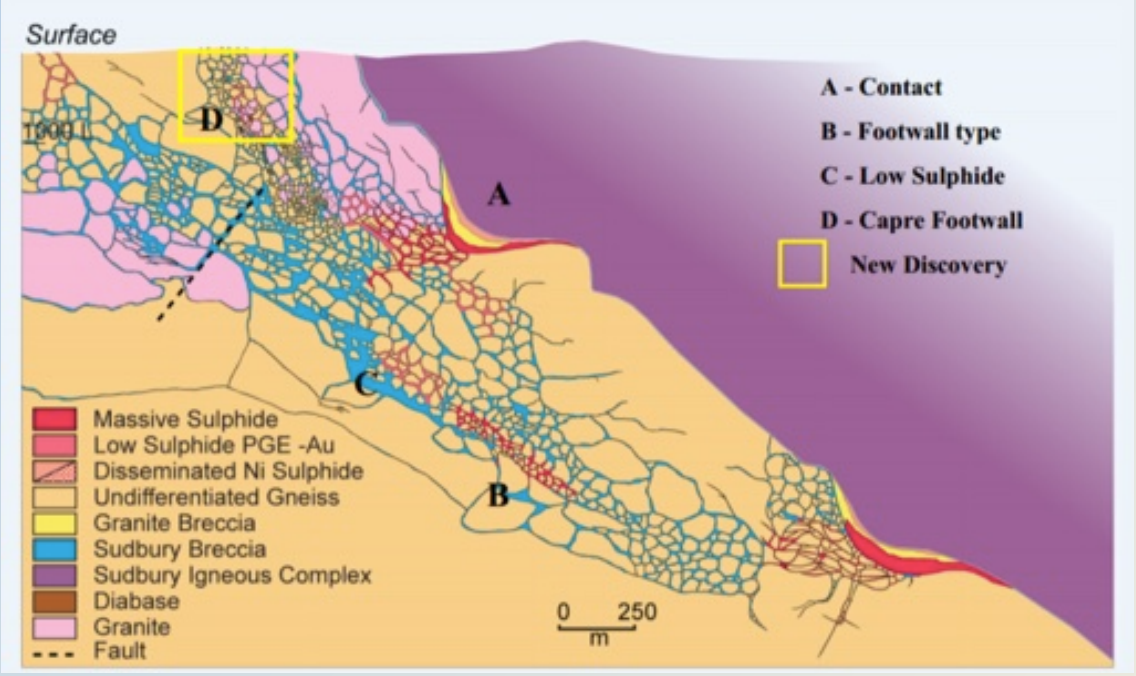

Image from Stewart and Lightfoot 2010

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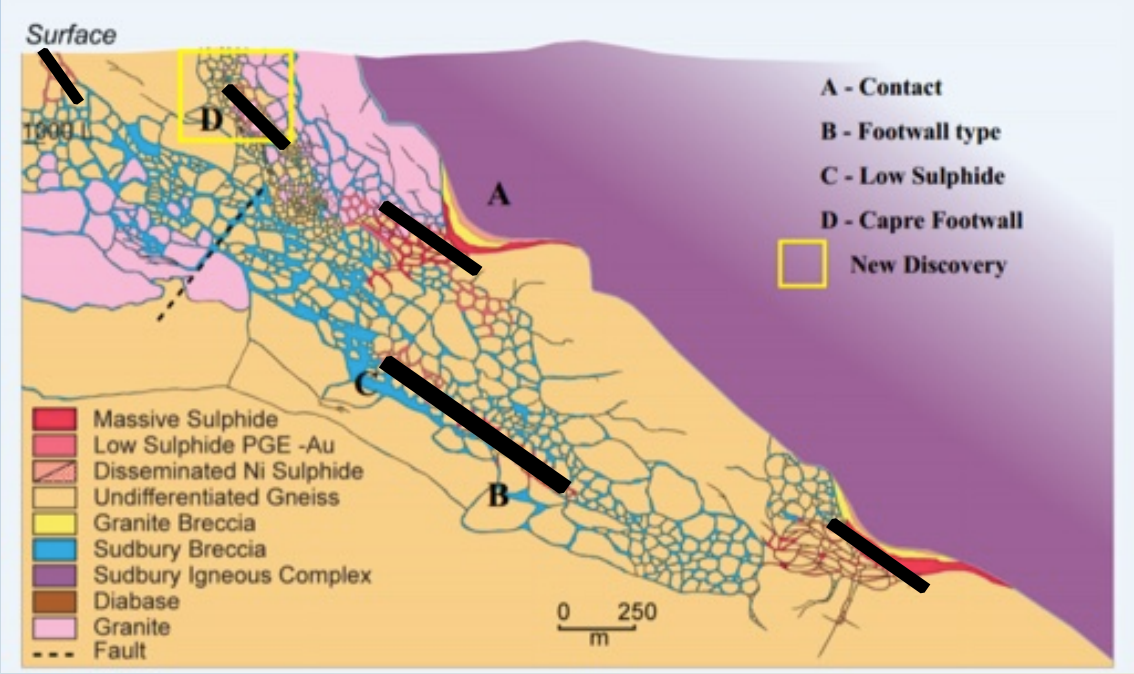

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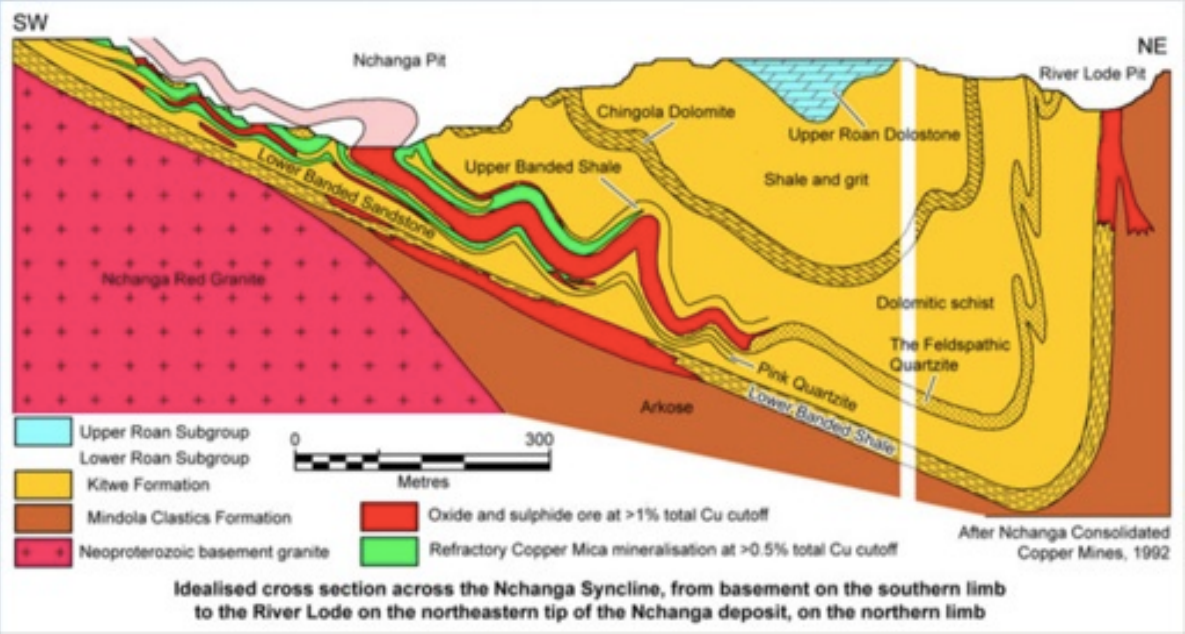

Idealised cross section across the Nchanga Syncline, from basement on the southern limb to the River Lode on the northeastern tip of the Nchanga deposit, on the northern limb

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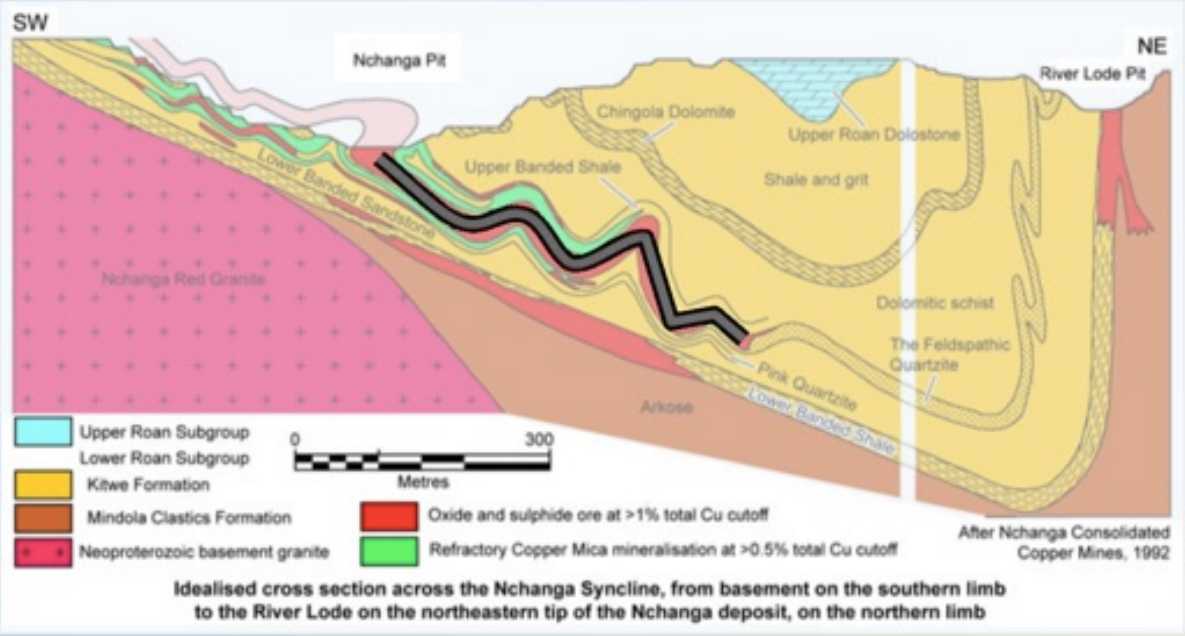

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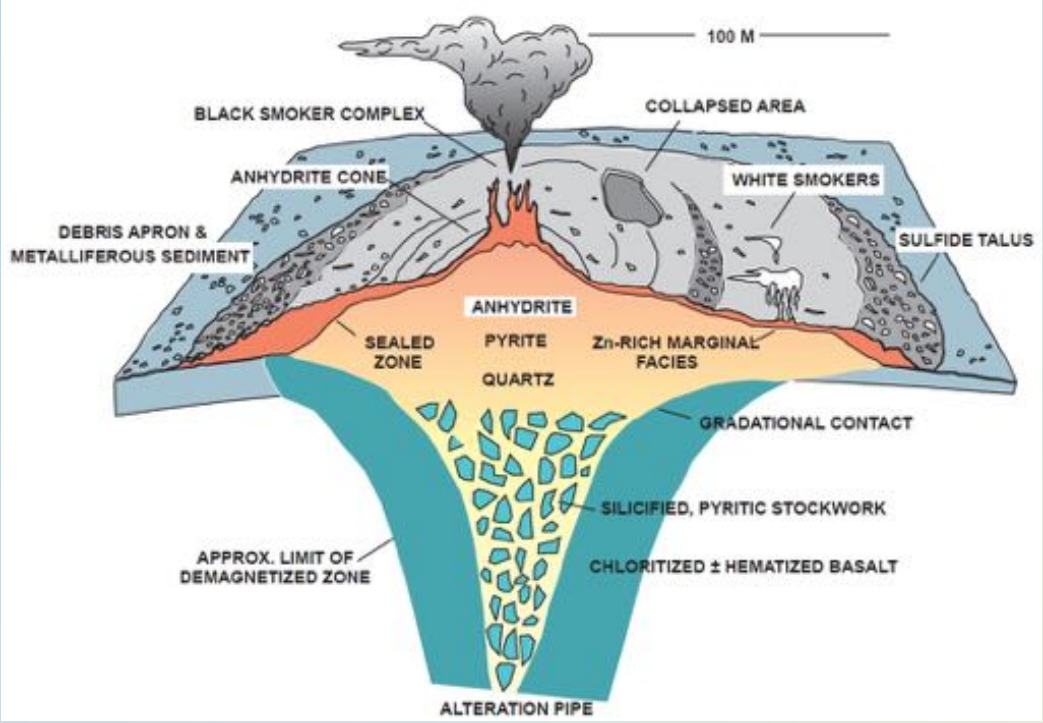

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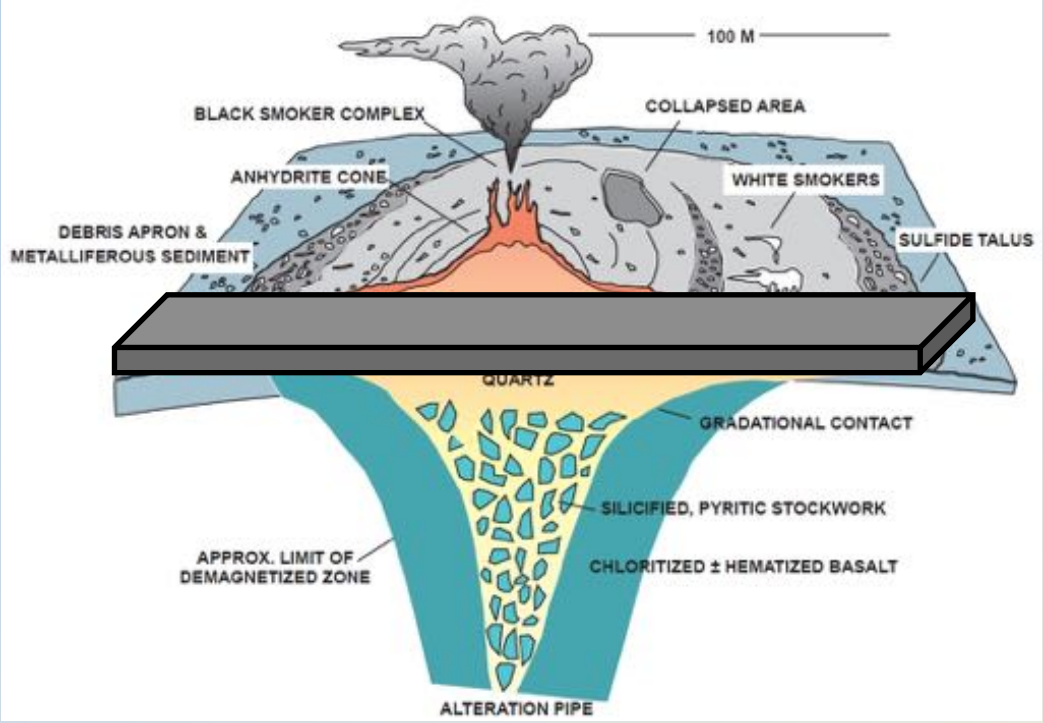


Image from Stewart and Lightfoot 2010

Parametric models - sphere

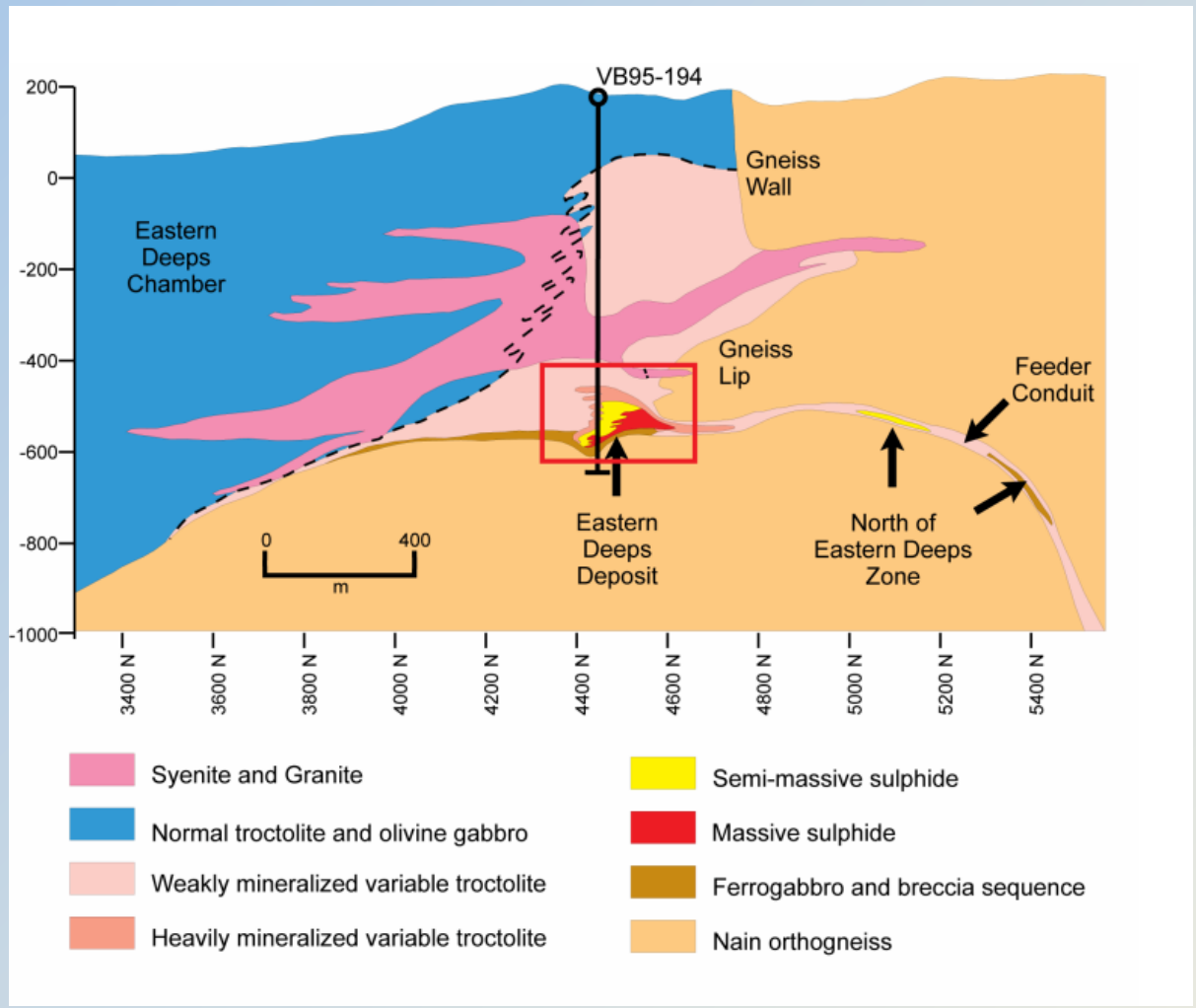


Image from Lightfoot 2007

Parametric models - sphere

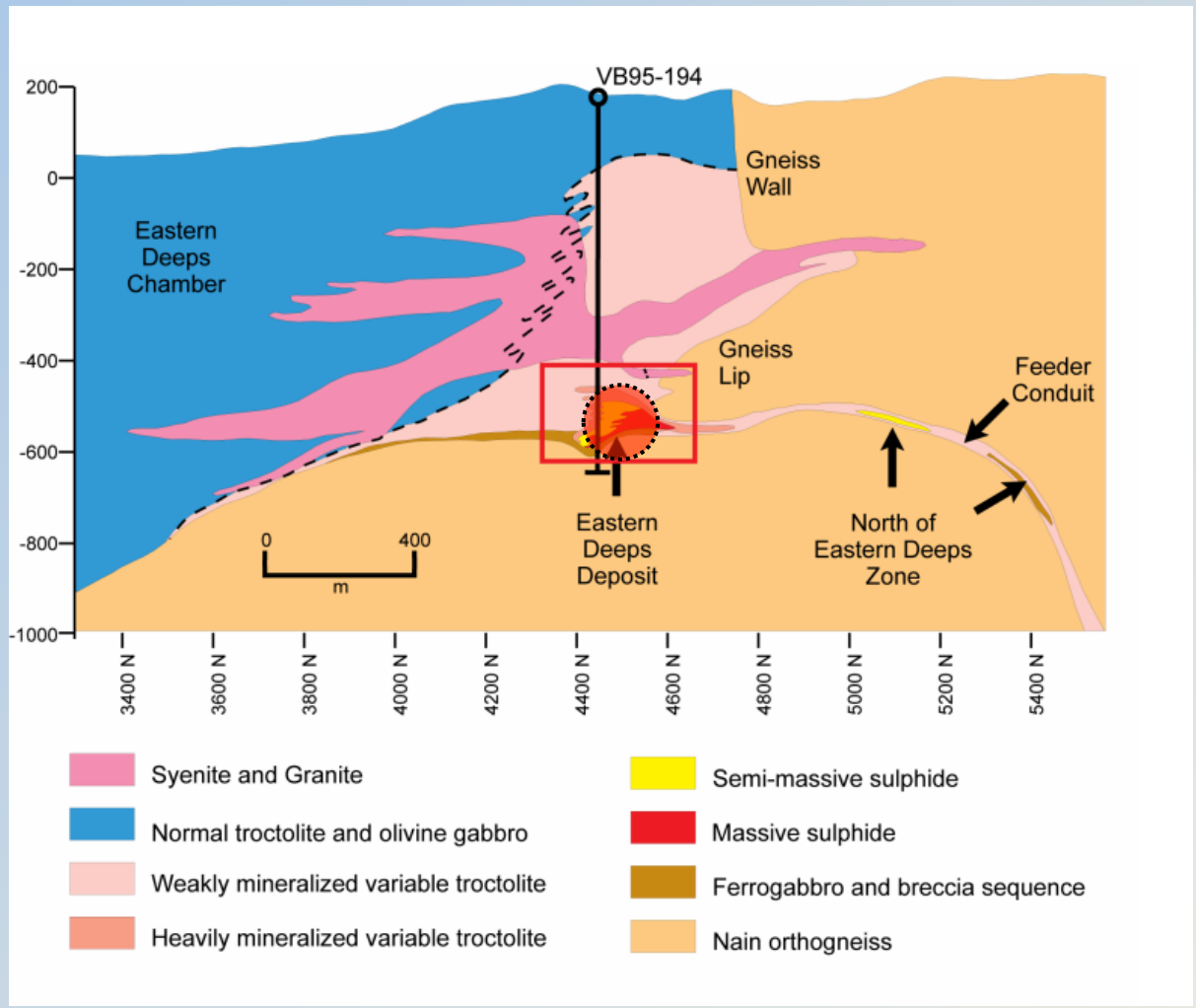


Image from Lightfoot 2007

Case Studies

Ovoid Deposit, Voisey's Bay, Labrador (MGEM)

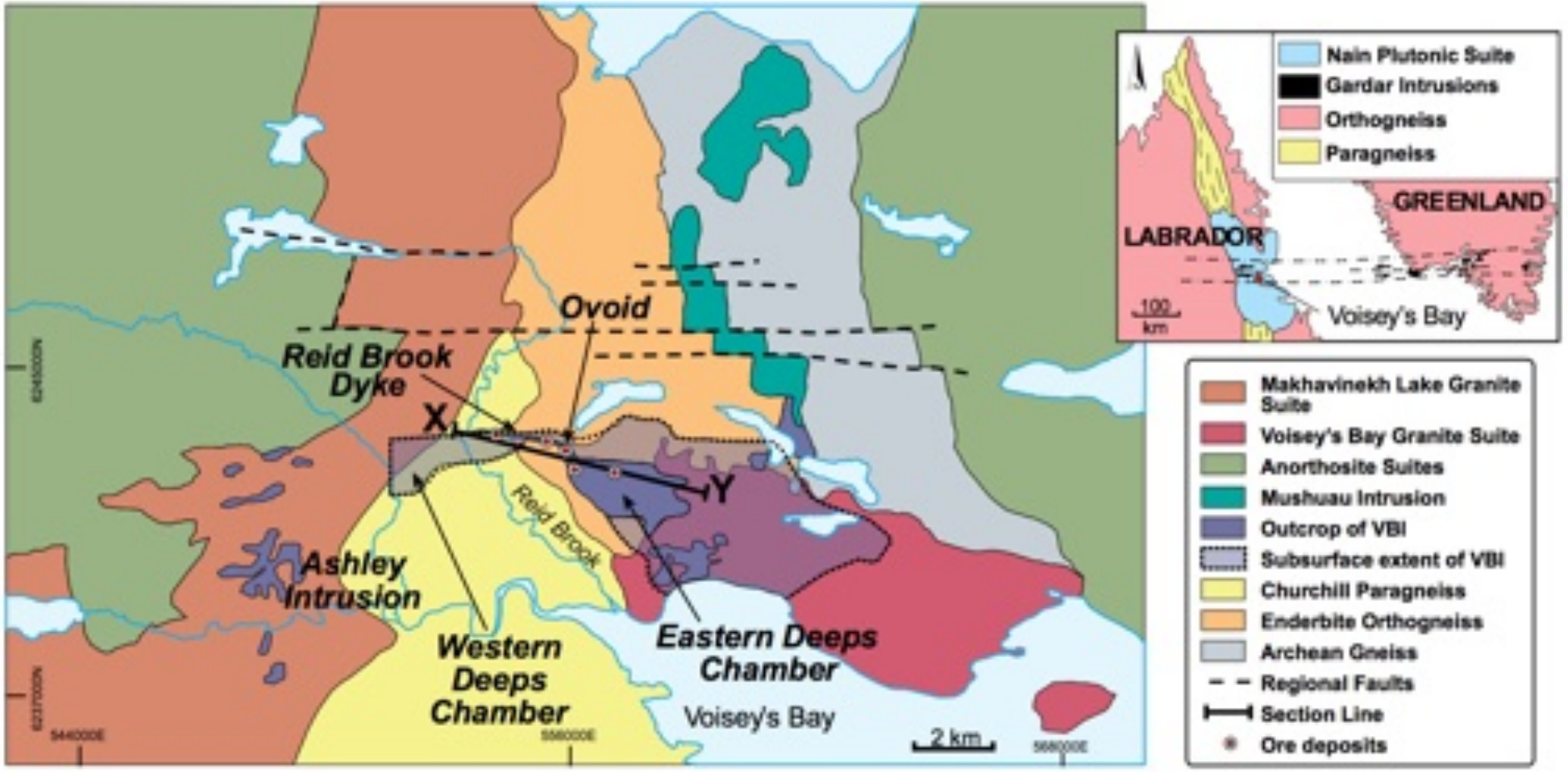
Sudbury Locations

Levack Footwall Deposit

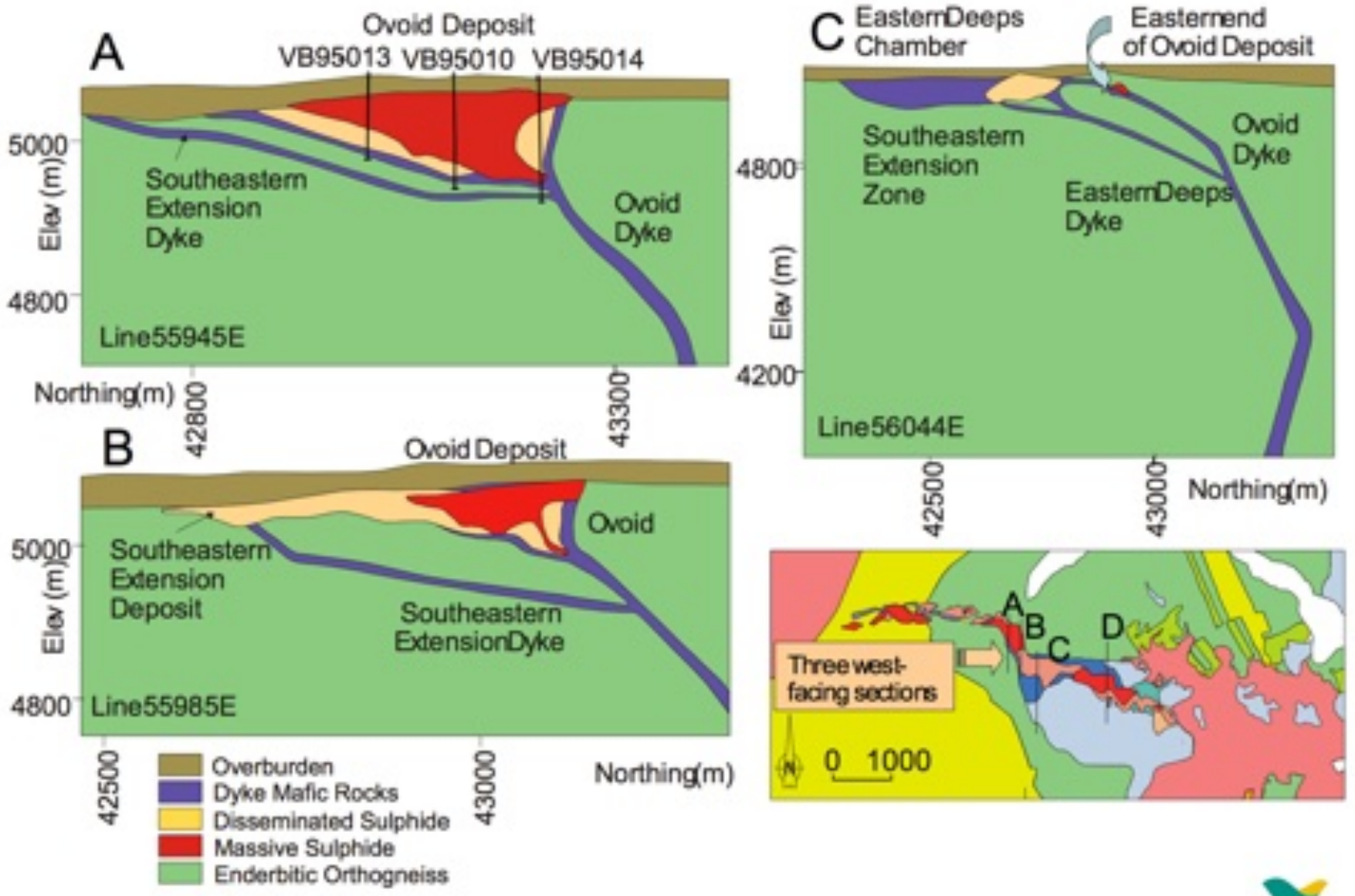
Nickel Rim South

Victoria Deposit

Geology of the Voisey's Bay Deposit



Geological relationships in the Ovoid



Lightfoot et al (2011)

Ovoid Deposit

Aerial View

Looking North

Massive Sulphide Ore – The Ovoid

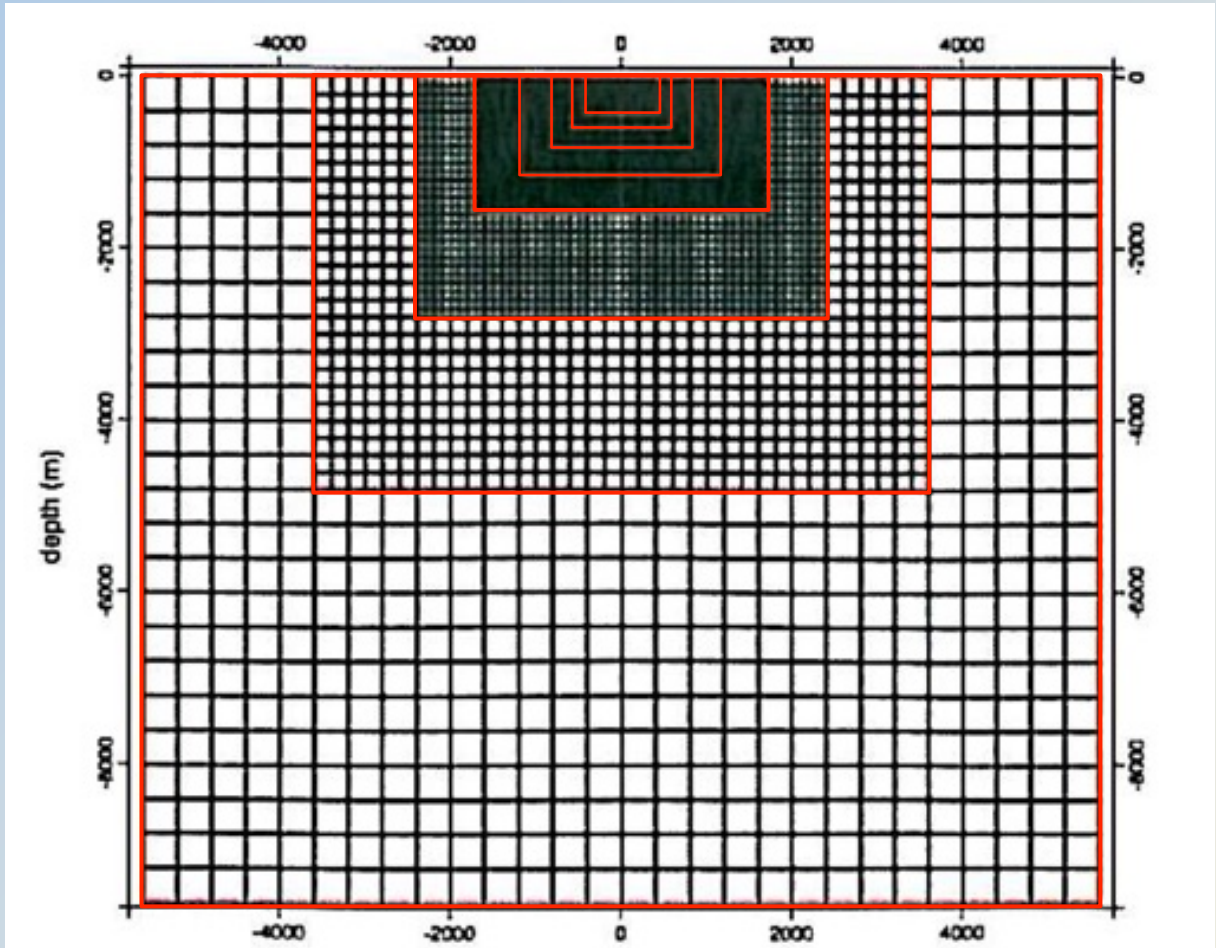
70% Pyrrhotite
15% Pentlandite
10% Chalcopyrite

Inco purchased Ovoid for $4.3B
Vale purchased Inco for $18.2B
Ore Value mined $15B from Ovoid
Contains 3% Nickel, 2% Copper, 1% Cobalt - 37 million tonnes

Courtesy CBC News 2018

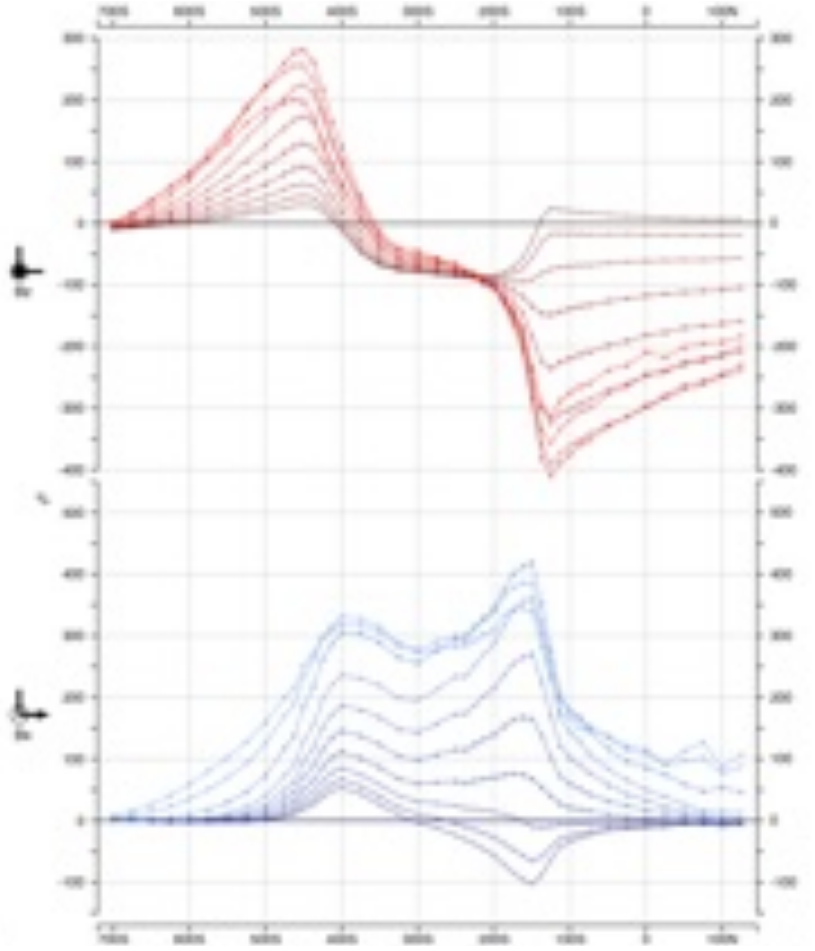
MGEM – Full MultiGrid EM Finite Difference Method Forward Modelling

X-section of the multigrid expanding below the earth's surface.
coarser-to-finer mesh boundaries shown in red



EM modelling

EM response of geology



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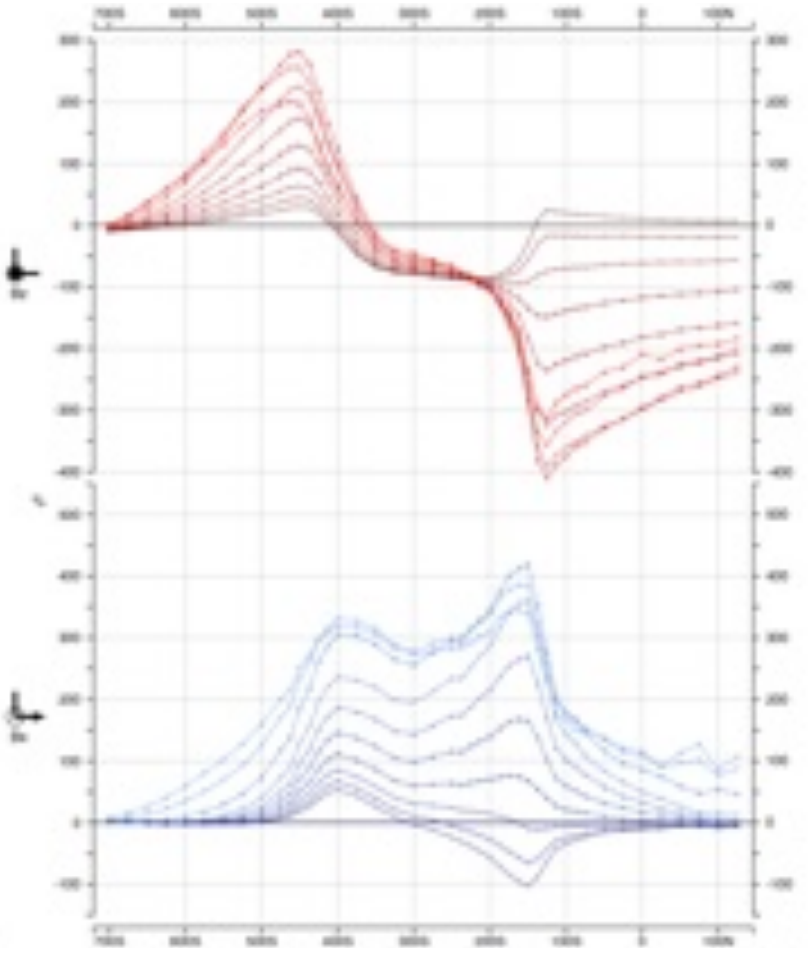
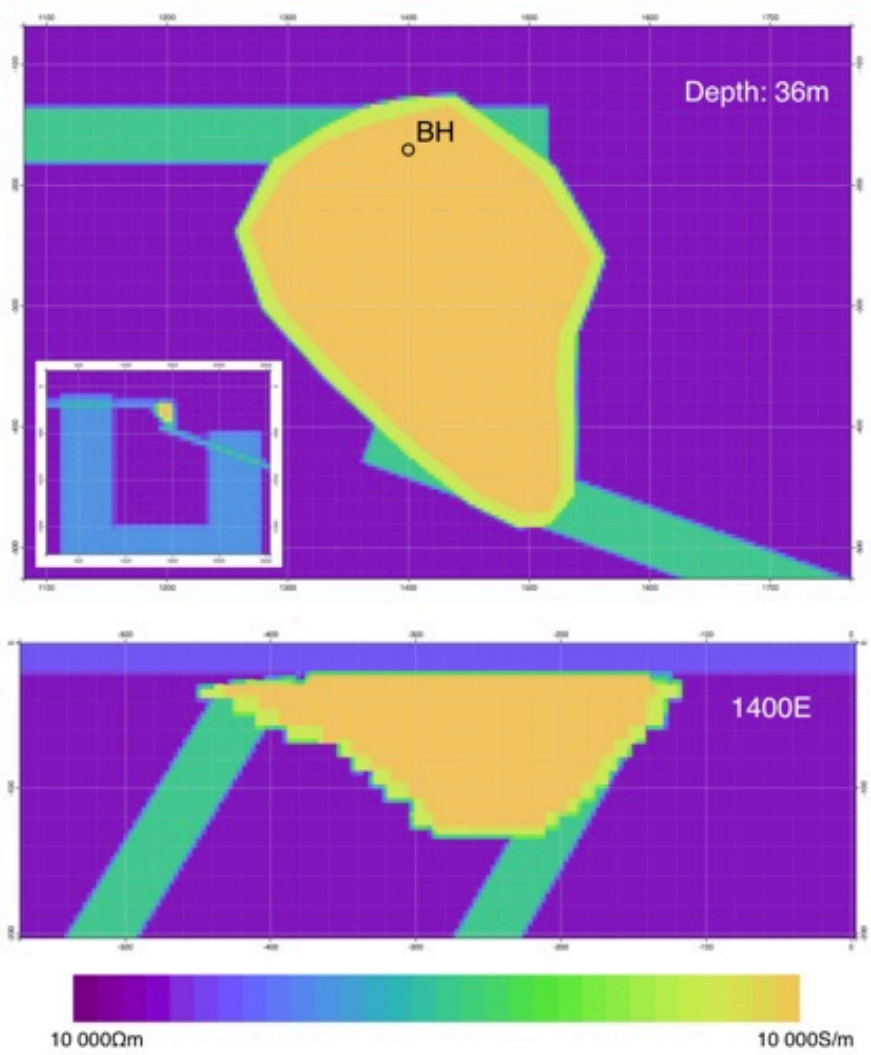
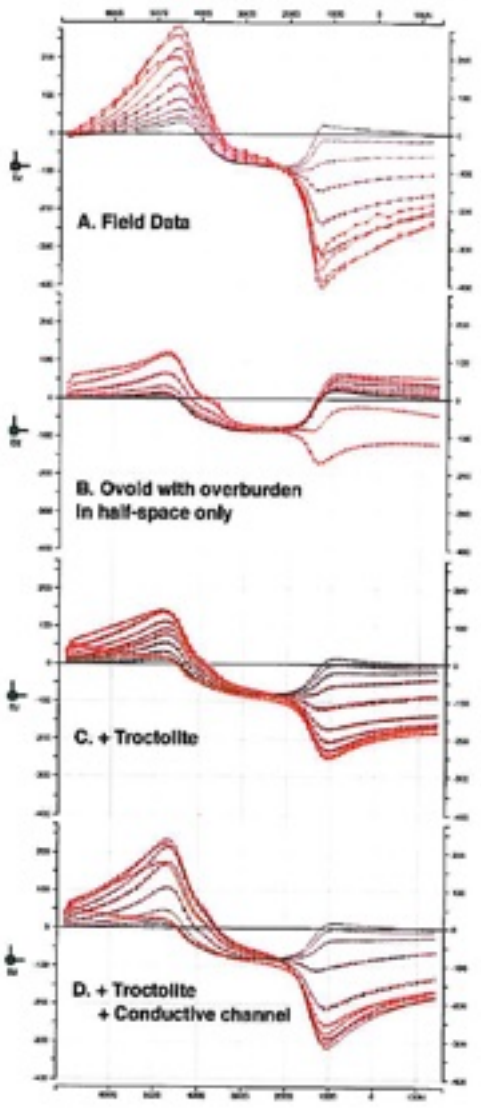
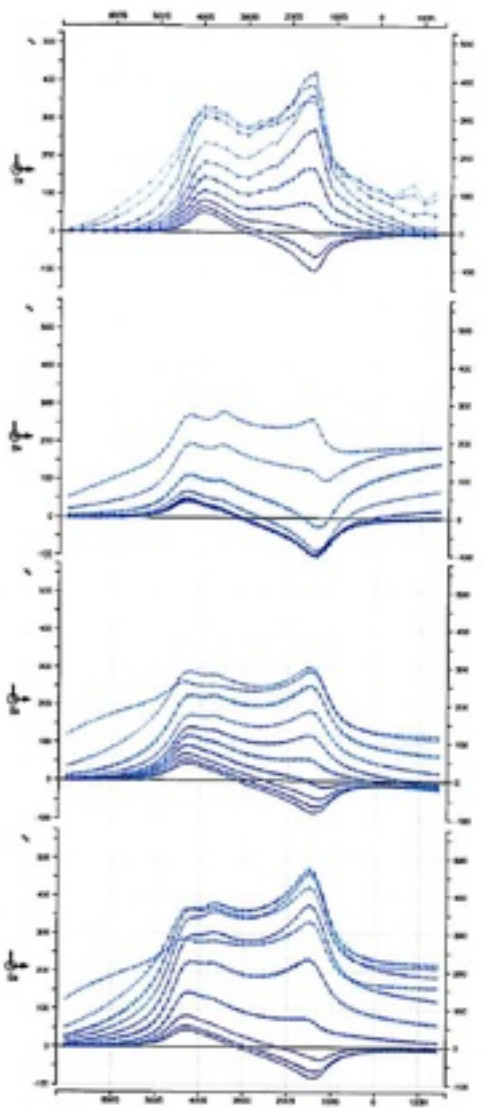


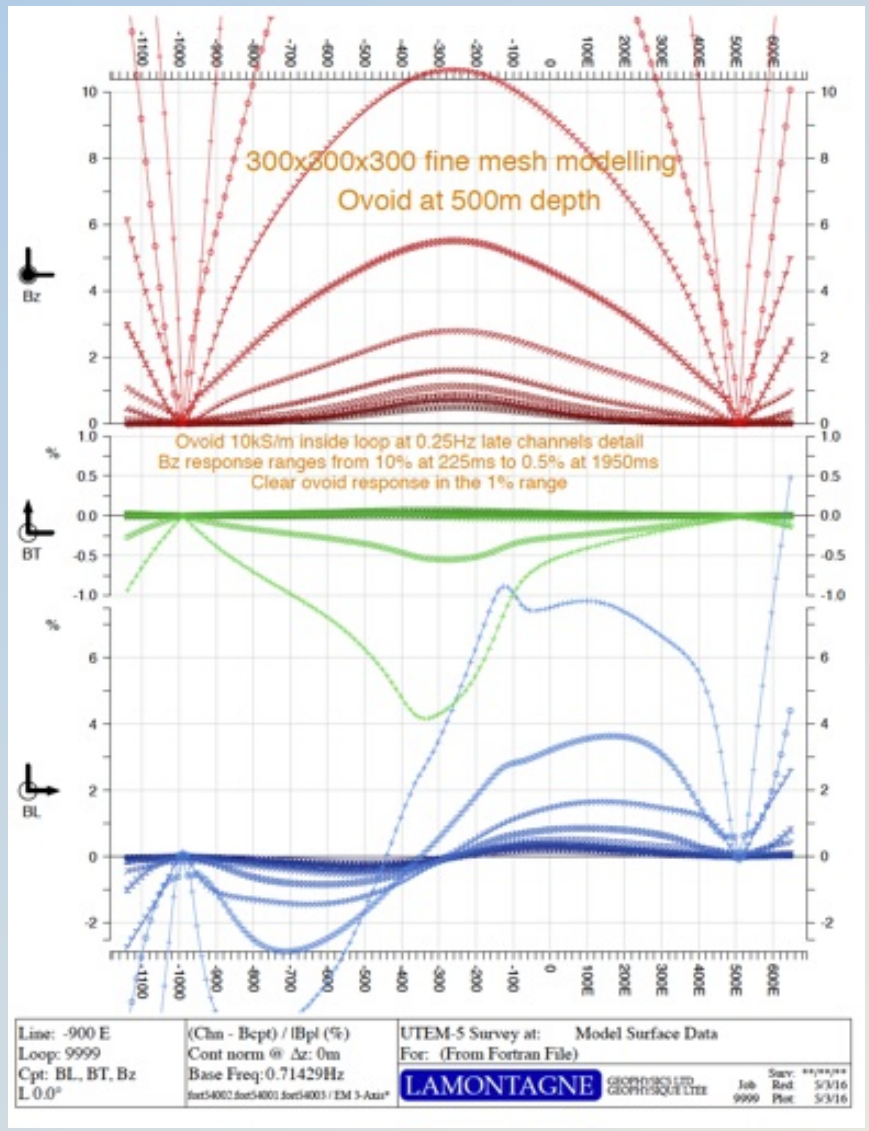
'Geology' model



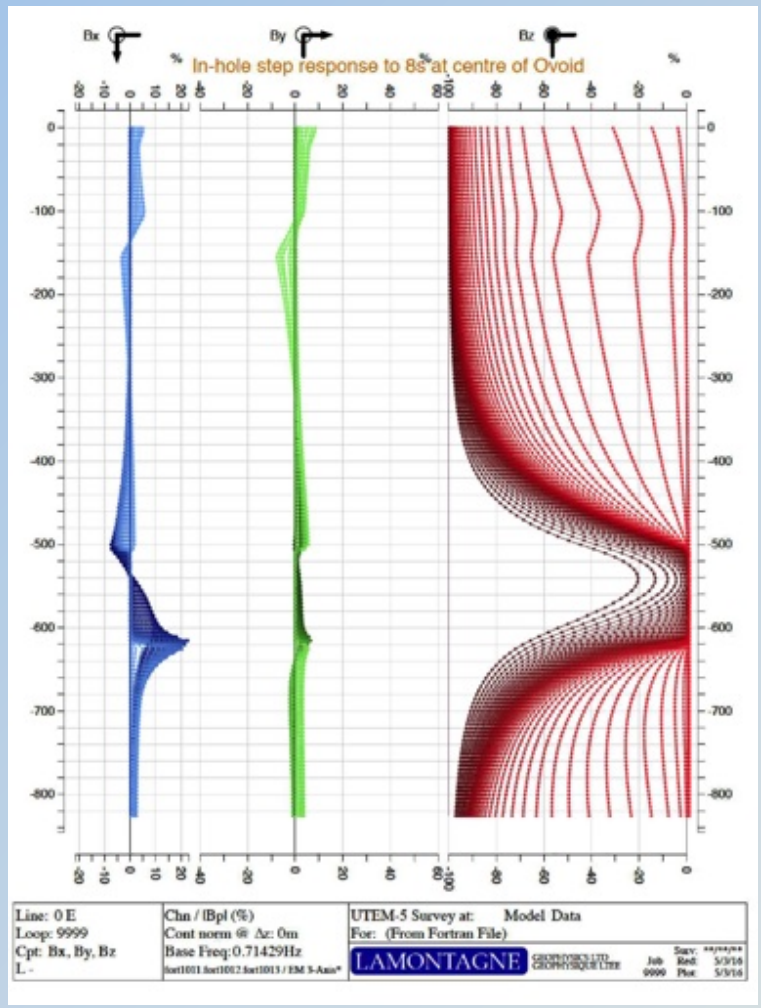

A. Field Data
B. Ovoid with overburden
in half-space only
C. + Troctolite
D. + Troctolite
+ Conductive channel



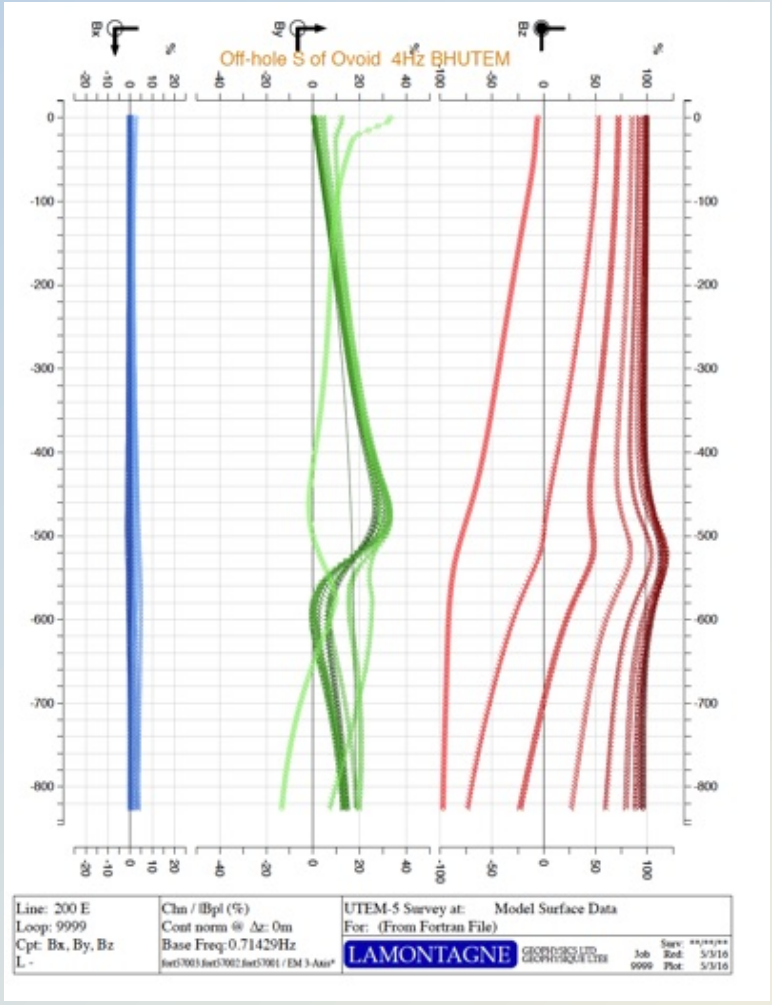
Voisey's Bay Ovoid @ 500m Depth



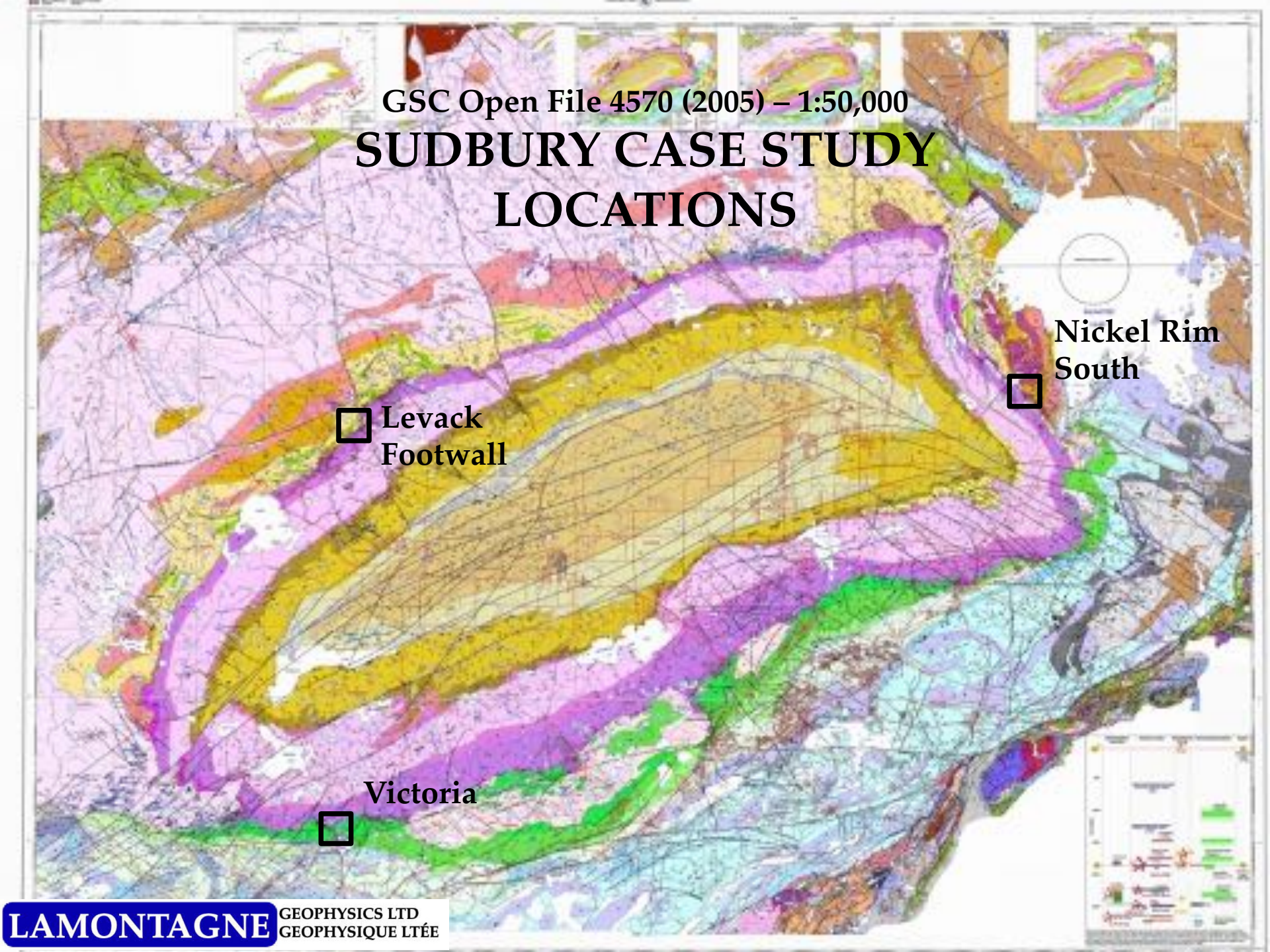
Ovoid modelled drilling

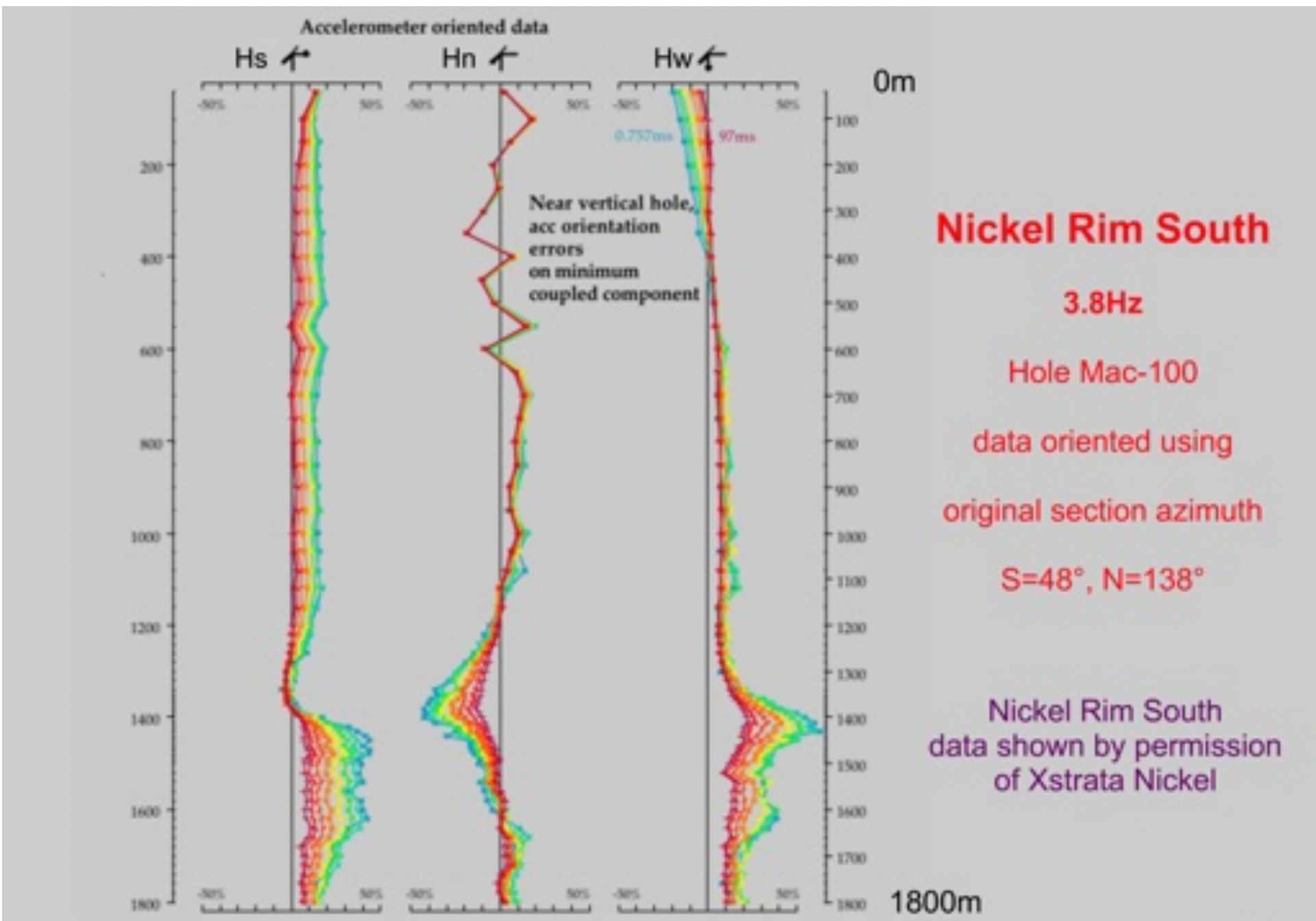


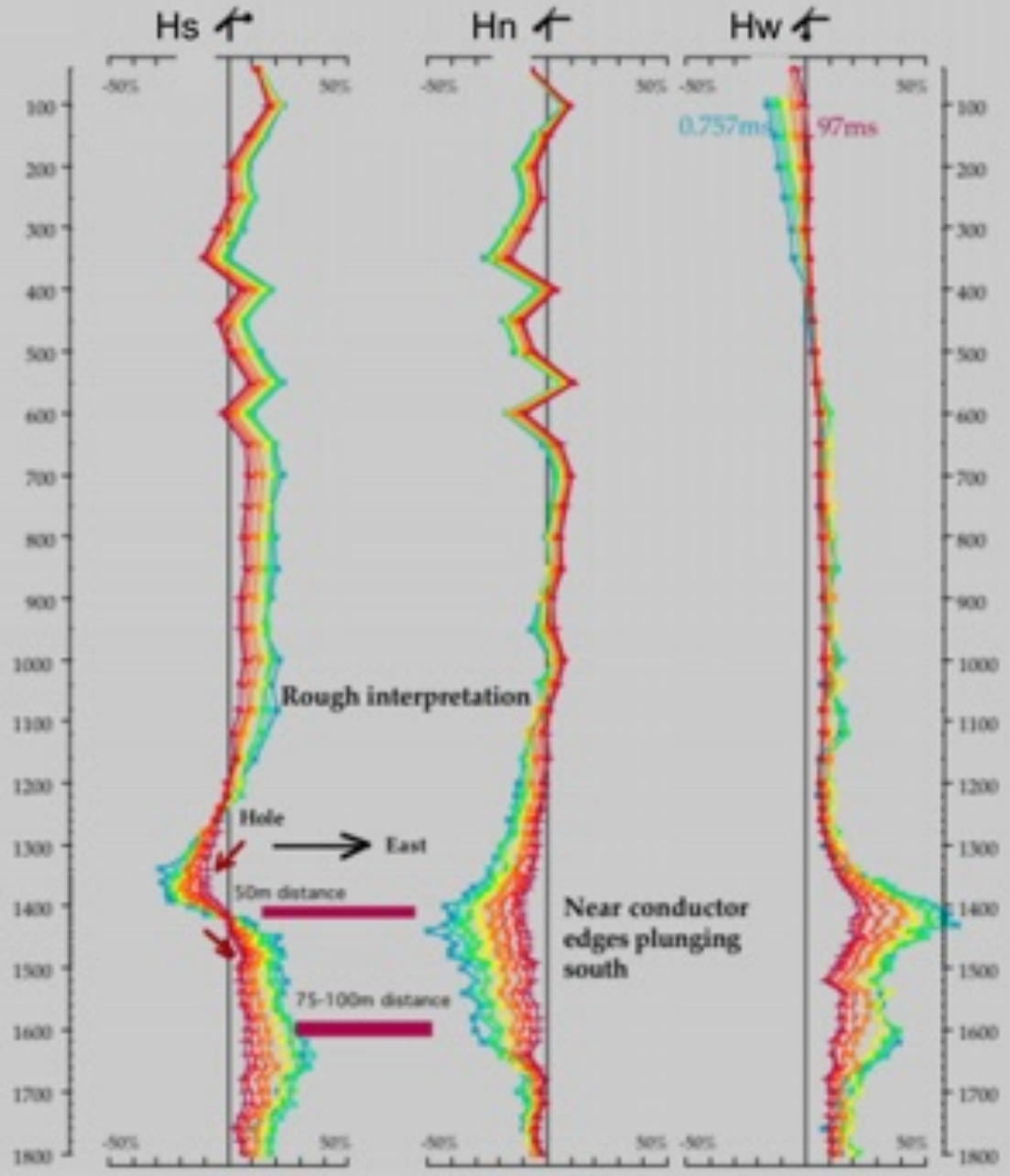
Predicted in-hole response in Centre of Ovoid



Predicted off-hole response South of the Ovoid


GSC Open File 4570 (2005) – 1:50,000
SUDBURY CASE STUDY LOCATIONS
Nickel Rim South
Levack Footwall
Victoria
LAMONTAGNE GEOPHYSICS LTD GEOPHYSIQUE LTÉE


Accelerometer oriented data
Hs
Hn
Hw
0m
1800m
Near vertical hole,
acc orientation
errors
on minimum
coupled component
Nickel Rim South
3.8Hz
Hole Mac-100
data oriented using
original section azimuth
S=48°, N=138°
Nickel Rim South
data shown by permission
of Xstrata Nickel



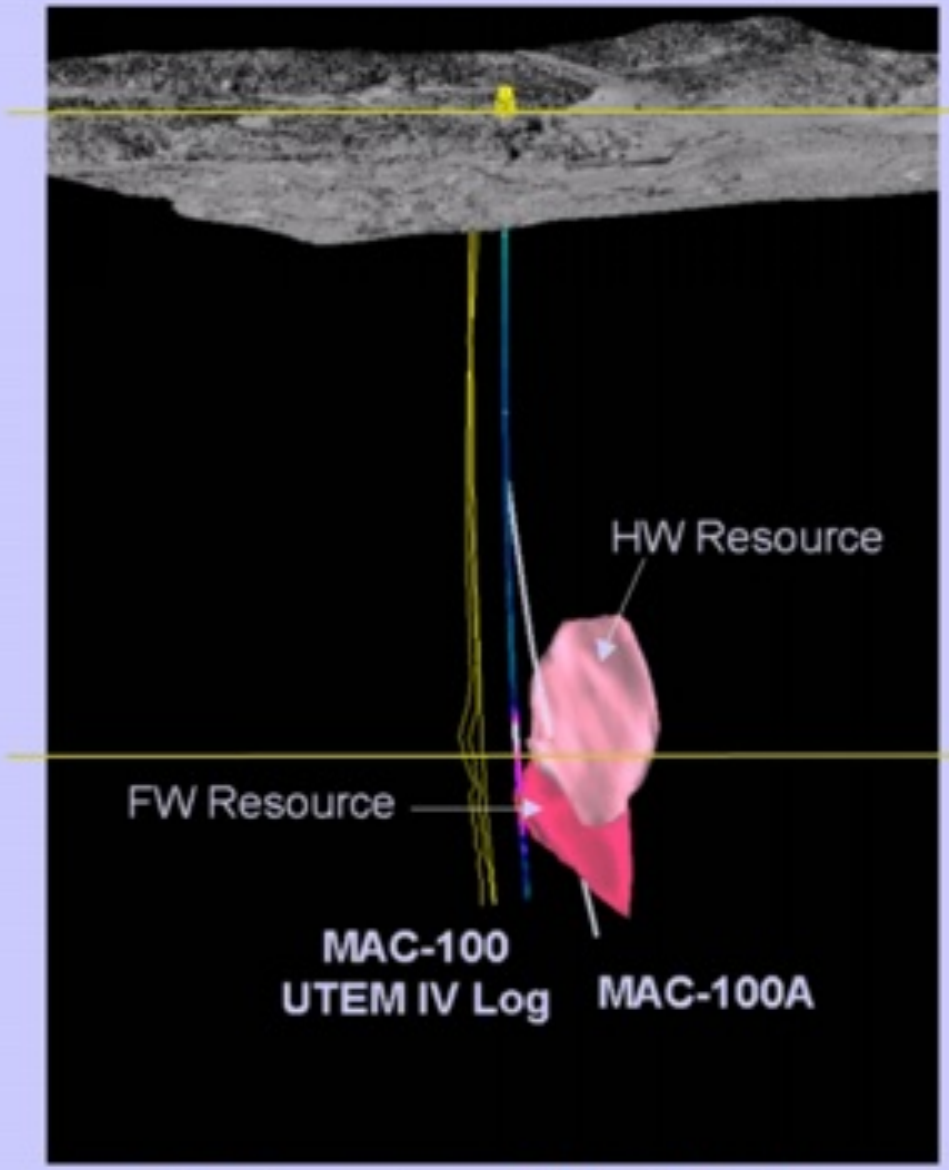
Nickel Rim South

Hole Mac-100

data oriented using

rotated section azimuth

S=90°, N=180°

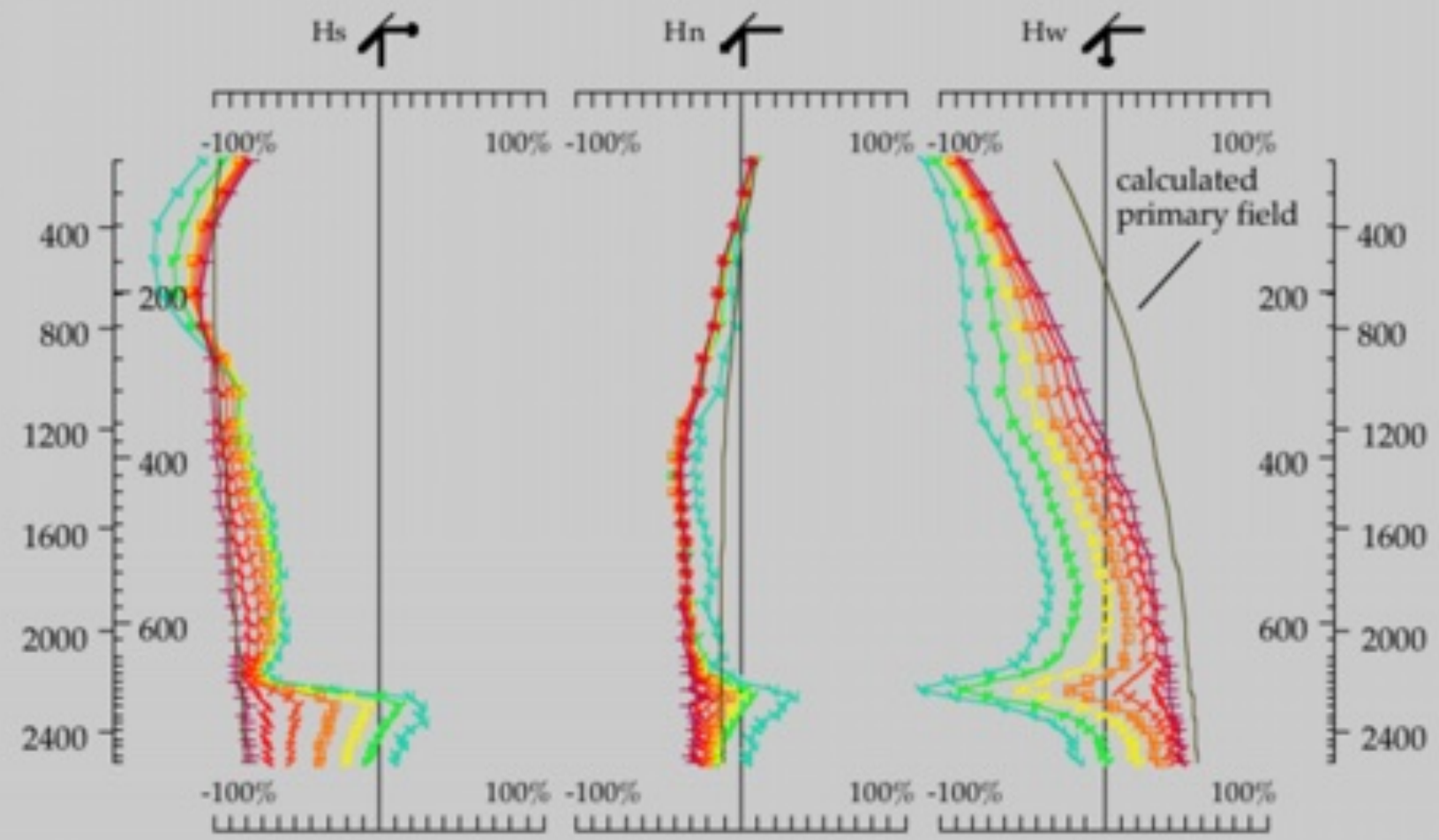


Nickel Rim South discoveries as currently defined by drilling

500m

500m

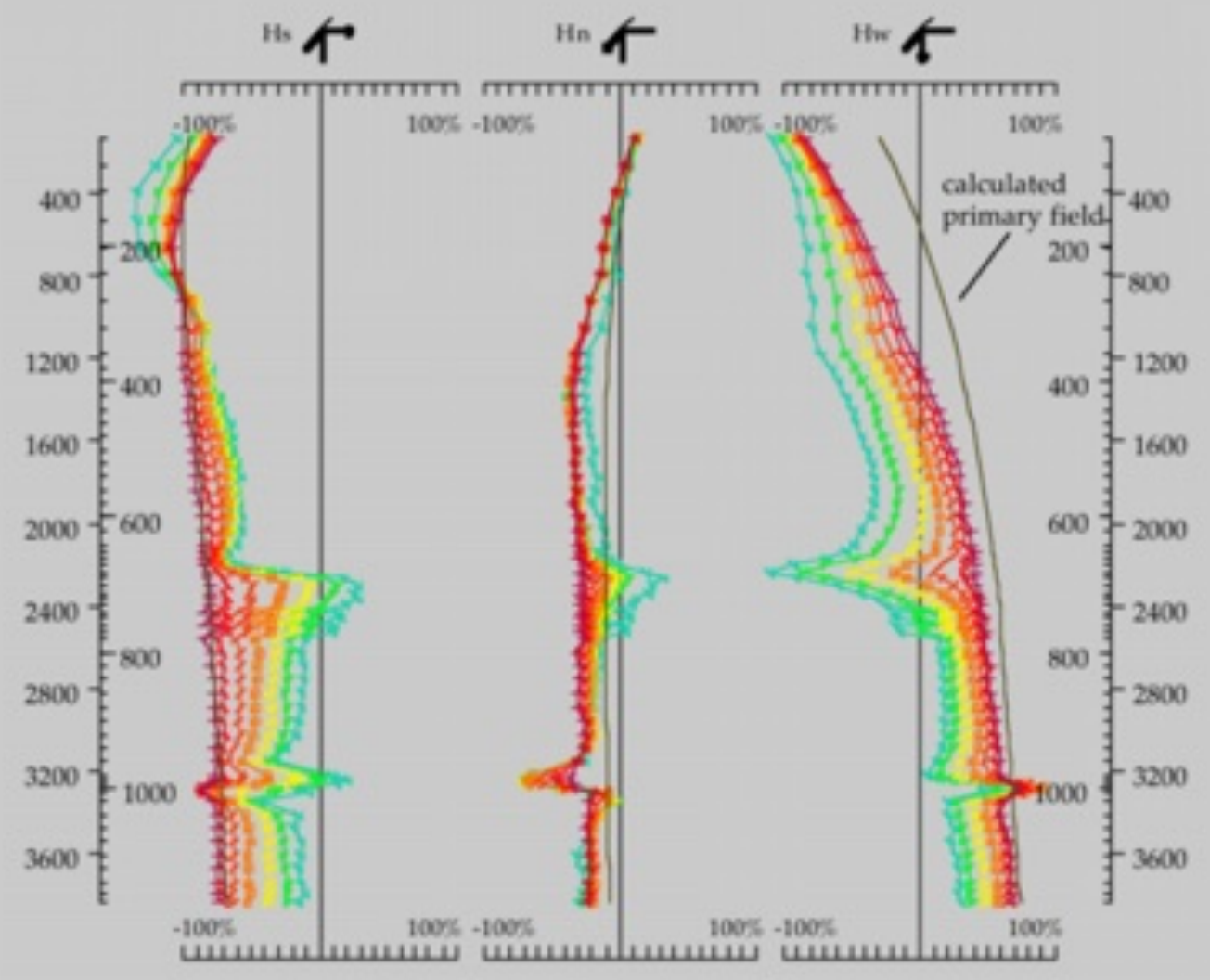
Drawing courtesy of Xstrata Nickel



Hole FNX-6010 April 2003 780m depth

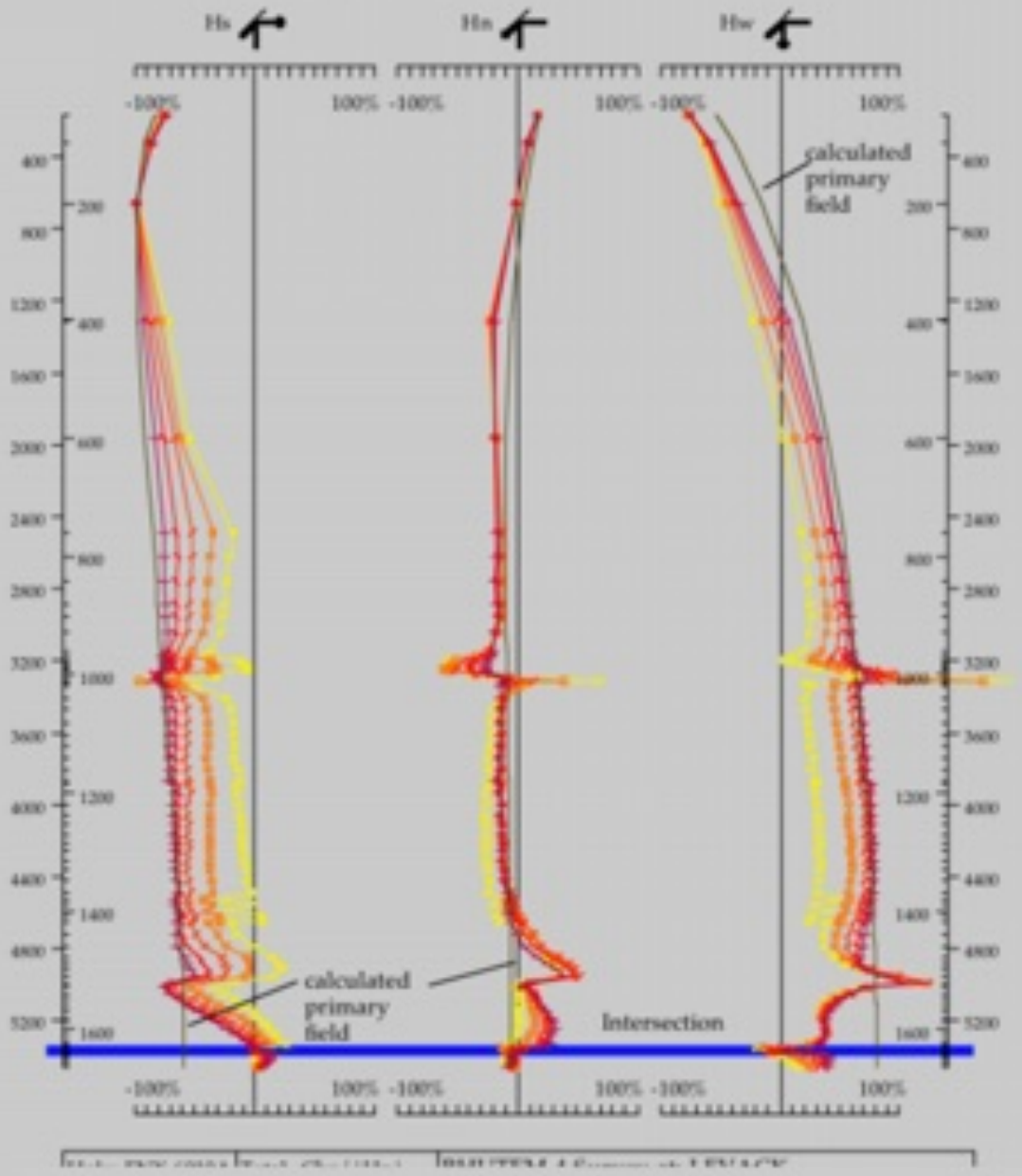
Levack Footwall

Levack Footwall data shown by permission of FNX Mining



Hole FNX-6010 December 2004 1170m depth

Levack Footwall

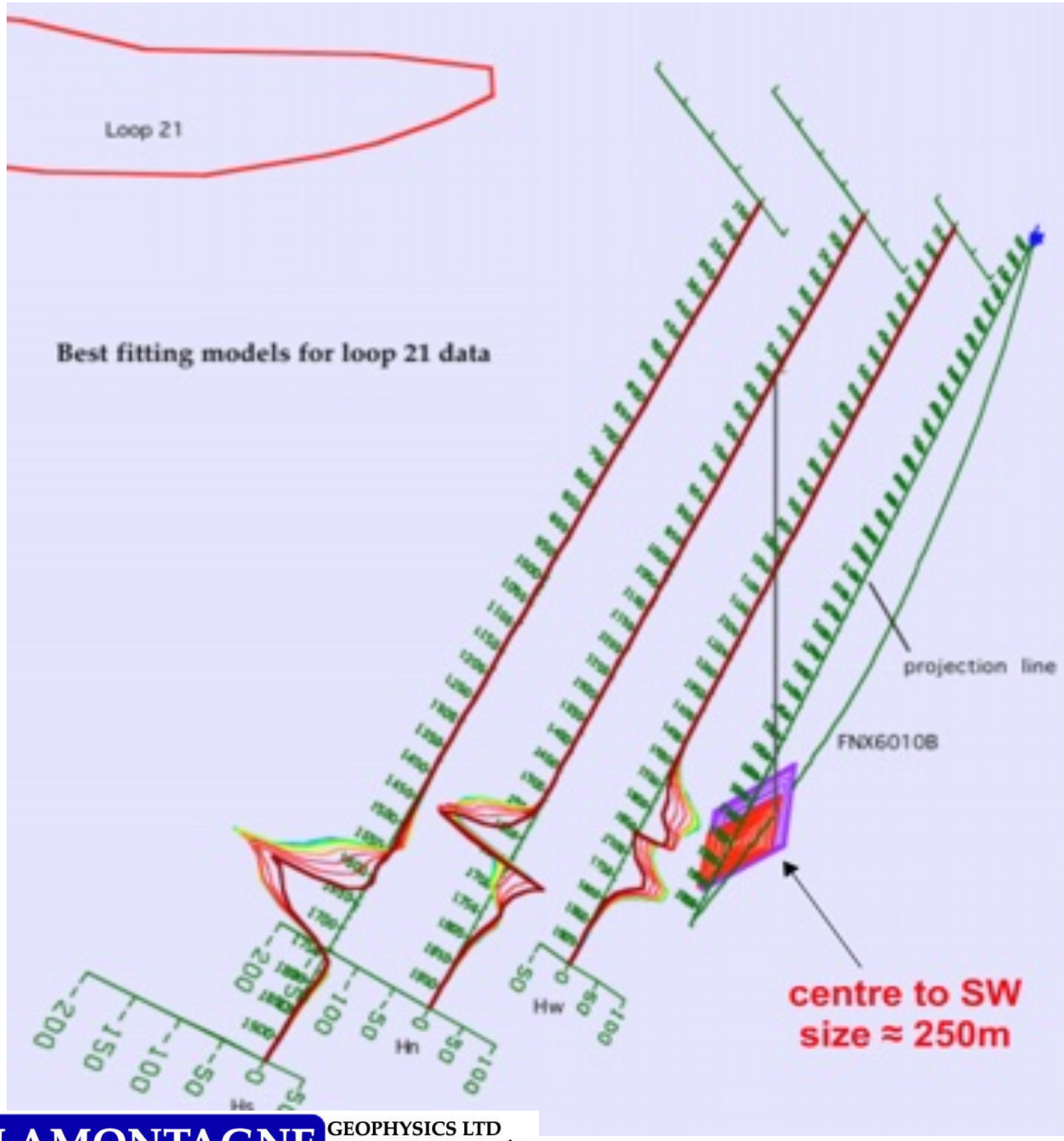


Levack Footwall discovery

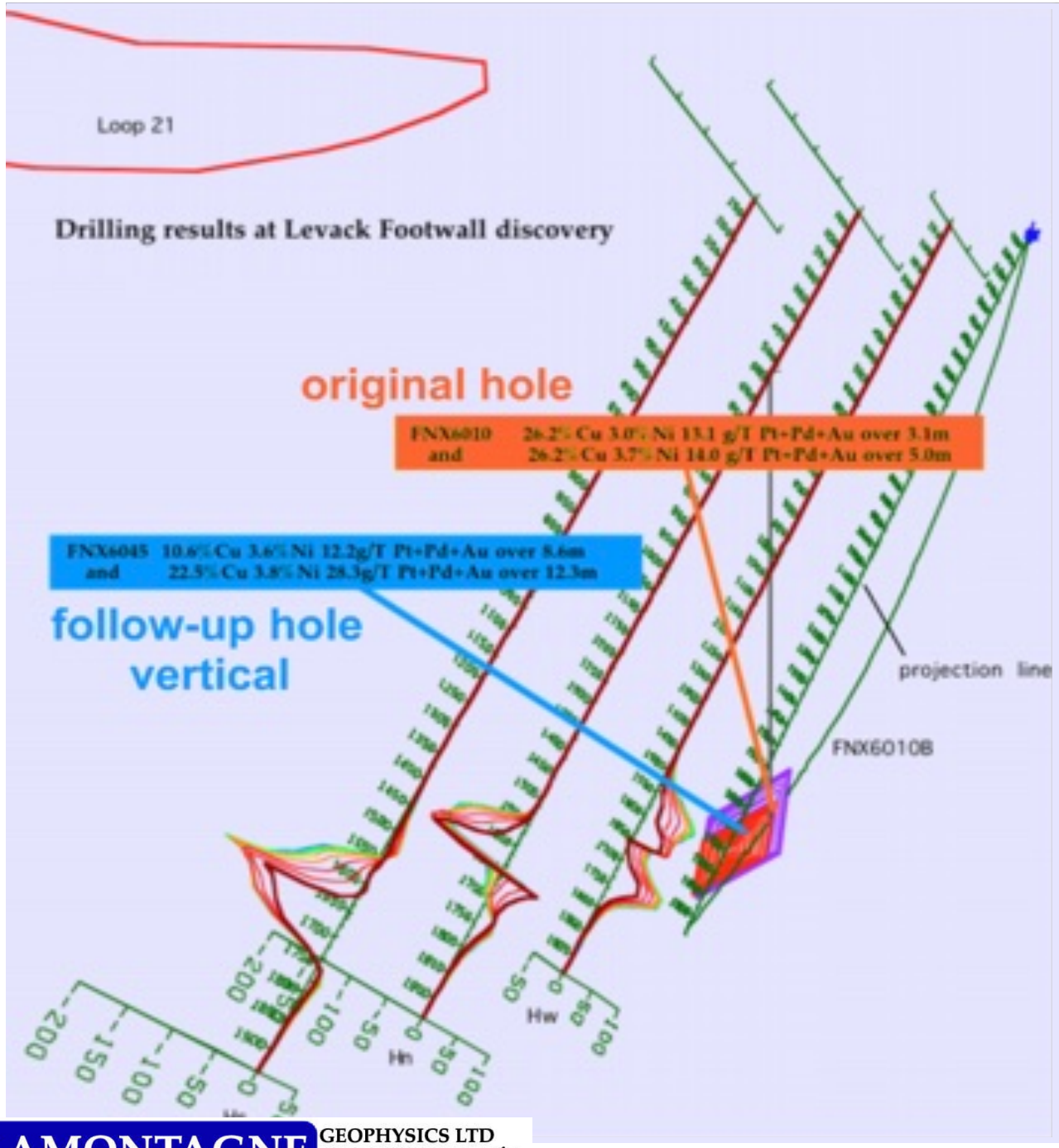
Hole FNX-6010 February 2005 1670m depth

Levack Footwall

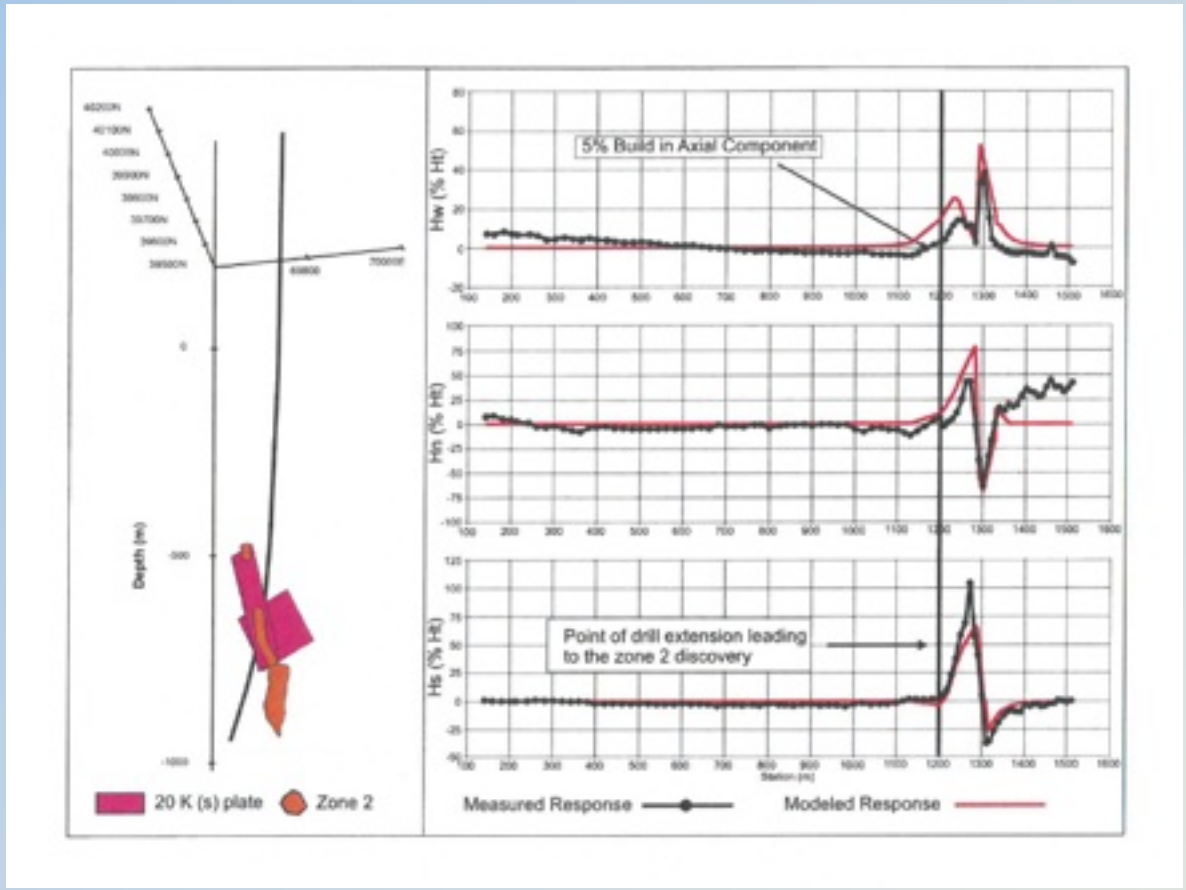
MultiLoop best fitting model



Levack Footwall follow-up drilling

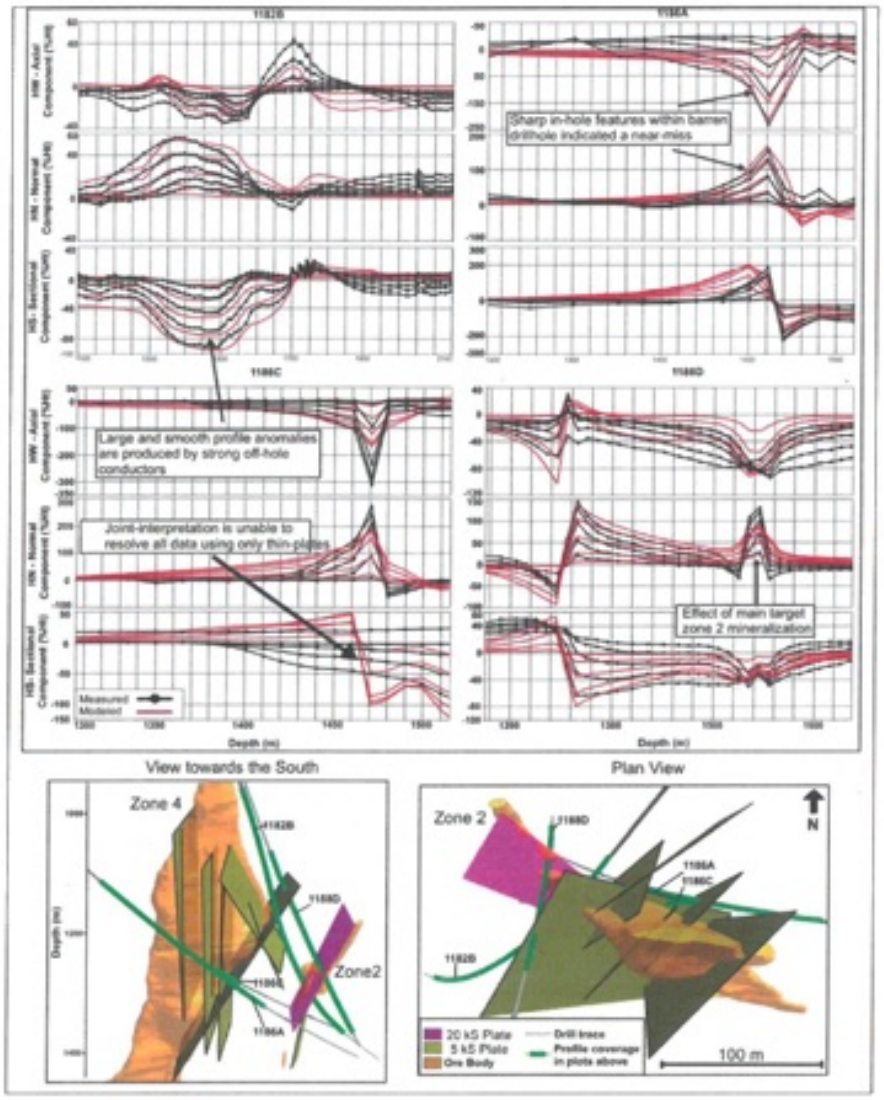


Victoria deposit



UTEM channel 1 measured (Black) and modeled (Red) profile response of Drillhole FNX 1178. A 5% build in the Hw axial component was recognized and suggested a conductor lay ahead. Extending this hole resulted in the intersection of Zone 2 and a resulting strong EM response.

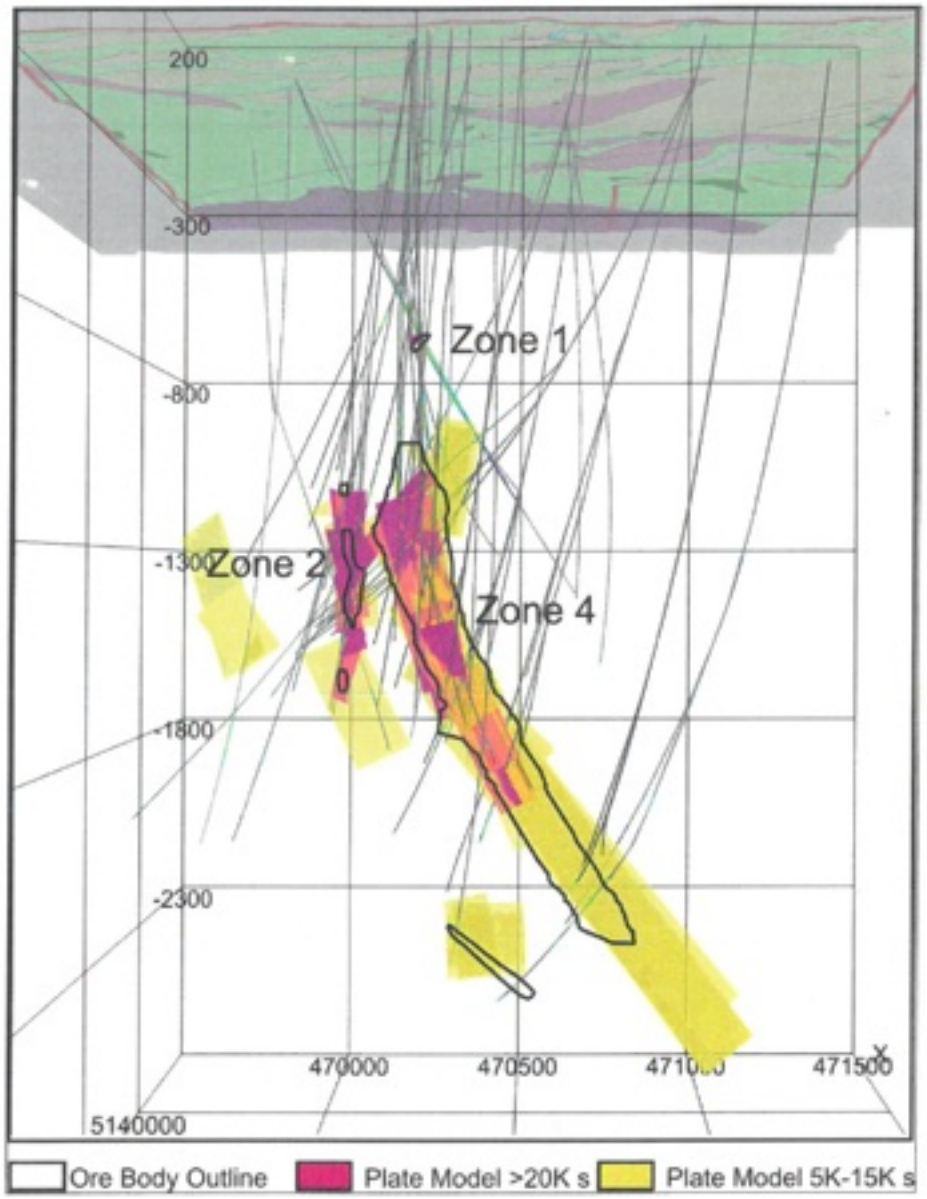
Victoria deposit



Measured (**black**) and modeled (**red**) response profiles from joint interpretation of FNX1182B, 1186A, 1186C and 1188D.

Off-hole responses and near miss in-hole features resulted in the mass of plates which approximate Zone 4 of the Victoria Deposit.

Portions of drillholes displayed within EM profiles are highlighted by green outline.



Victoria Deposit

Deposit starts 1132m below Surface.

Drillhole FNX 1190 intersected 417m of 1.3% Copper, 0.6% Nickel, 2.2g/t TPM in Zone 4

Thin plate models suggests mineralization extends down plunge.

Borehole geophysical methods will most certainly remain crucial in defining Victoria's extent.

Reserves are 12.5Mt of 2.3% Copper, 2.2%Nickel and 8.5g/t TPM

Acknowledgements:

Lamontagne
Yves Lamontagne
Rob Sinclair (Consultant)
Rob Langridge
Owen Fernley (Consultant)
Michal Kolaj (NRCan)

KGHM/FNX
Bill Spicer (Lundin)
Steven Gregory

Vale
Sean Dickie
Peter Lightfoot (Consultant)
Alan King (Consultant)
Ben Polzer (Nova Solutions)

Glencore Sudbury
Warren Hughes
Tony Watts (Consultant)

References:

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KGHM International Limited.