Talk Outline: UTEM

History and Development of Lamontagne Geophysics Ltd.

Who was Yves Lamontagne?

What is UTEM?

Notable Developments

UTEM 5 coupled with Borehole UTEM (BHUTEM4+)

Interpretation (Modelling of EM data)

Successes

Borehole in the office

Zero Field Gauss Chamber

Awards

Other Contributions

Acknowledgements

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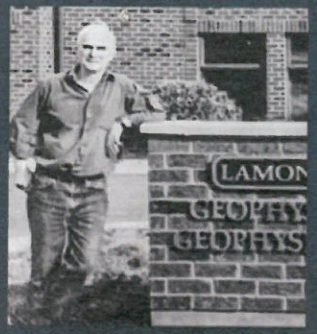
Yves LAMONTAGNE



YVES LAMONTAGNE OBITUARY

YVES JOSEPH ANDRÉ LAMONTAGNE It is with immense sadness that Lamontagne Geophysics Limited announces the death of Yves Joseph André Lamontagne, at the age of 79. He died in Kingston, Ontario on January 16, 2023, with his family by his side. He leaves behind Lise, André, Lucie, Josée, Francine, Élaine and François. He had 2 brothers that pre-deceased him, Gills and Jacques . He also leaves many nieces and nephews behind. Yves devoted his life to the advancement of Geophysics working into his late 70s. Yves graduated in geological engineering from École Polytechnique de Montréal in 1967, then received a M.Sc. in 1970, and a PhD in 1975, both from the University of Toronto. In 1979 he founded Lamontagne Geophysics Limited that still operates today successfully. He has changed the lives of many people with his generous ways. Donations of remembrance to the Cancer Society in Yves memory would be appreciated.

Published by The Globe and Mail from Jan. 18 to Jan. 22, 2023.

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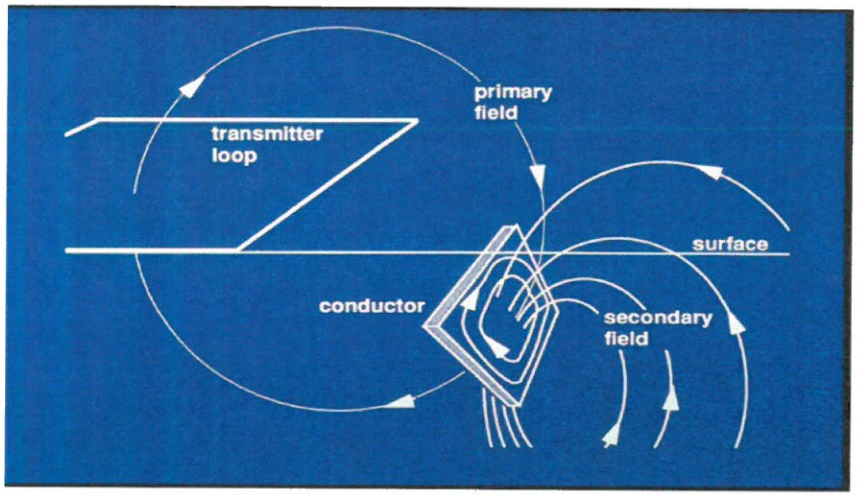
UTEM system
University of Toronto Electro-Magnetic system

UTEM is a wide band time domain surface EM system with a step function system response. Designed to achieve the sensitivity and interpretability necessary to handle problems of deep exploration with the main objective being the search for massive sulphide mineralization.



Schematic Layout
of a UTEM Survey

Yves Lamontagne commercialized the system in 1979. Since that time the system has been continuously improved and developed.

The operational system now available is UTEM 5.

The UTEM5 system collects, a wide dynamic range, 3-component EM data from up to 3 transmitter loops - three coupling angles – simultaneously – translating to superior target definition and improved detection of all targets. Capability to detect anomalies down to 0.01pT @ 5Hz and above.

All components of system are linear with exact PE-DC (Step Response) through all time. Provides uniform sensitivity, allows for discrimination between conductors.

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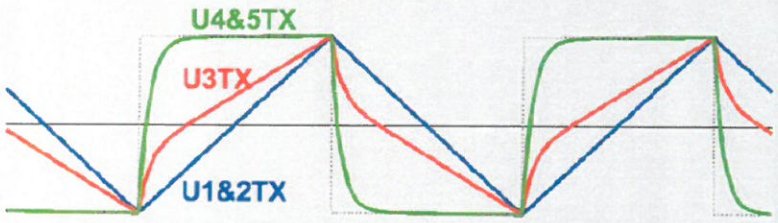
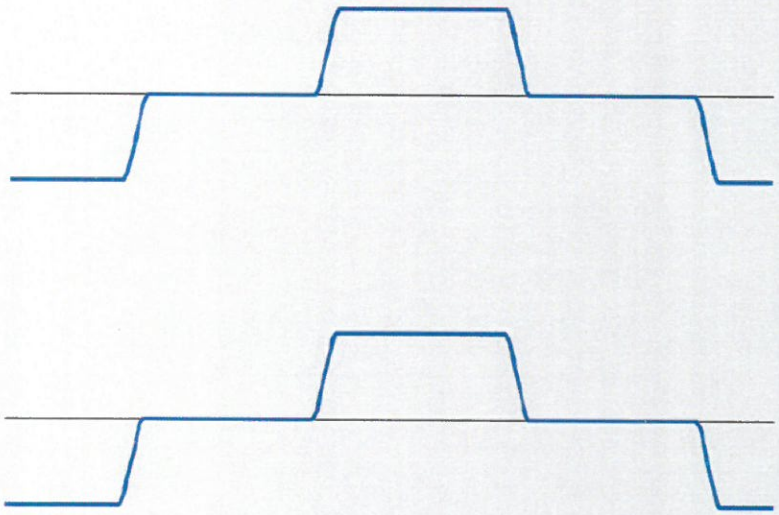
The TX current waveform is not the system response

TX CURRENT WAVEFORM



U4/U5 have high levels of pre-emphasis

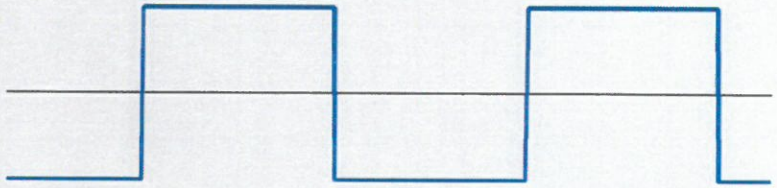


UTEM

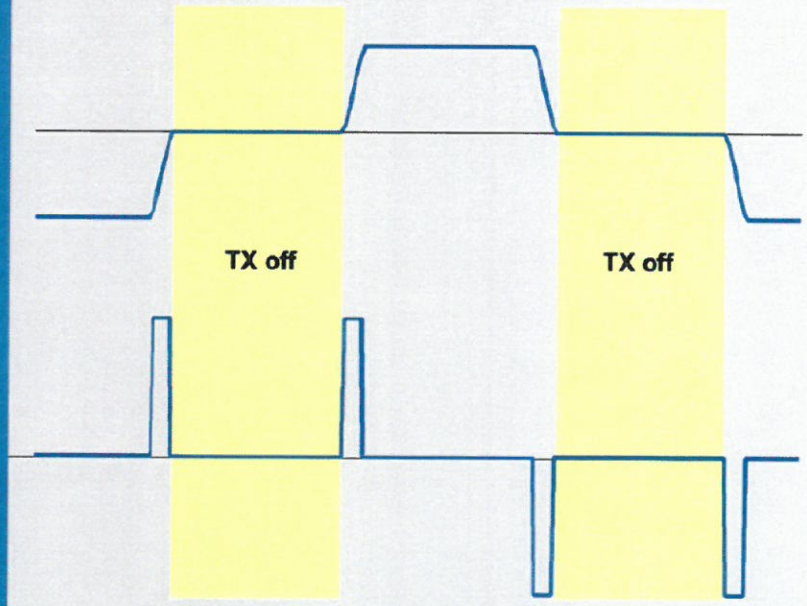
CASTLE B FIELD

CASTLE dB/dt

SYSTEM RESPONSE WAVEFORM



UTEM after exact PE-DC deconvolution



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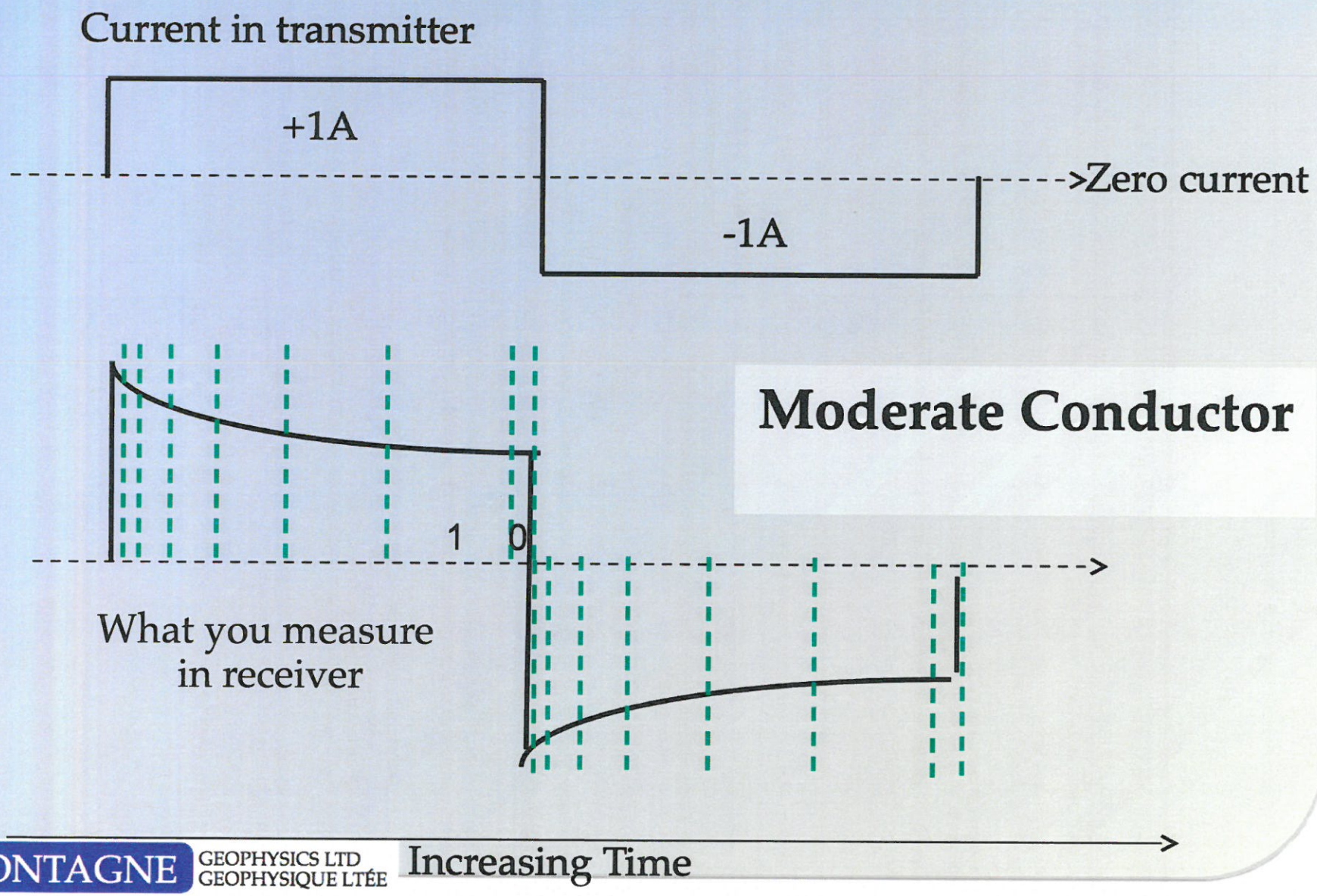
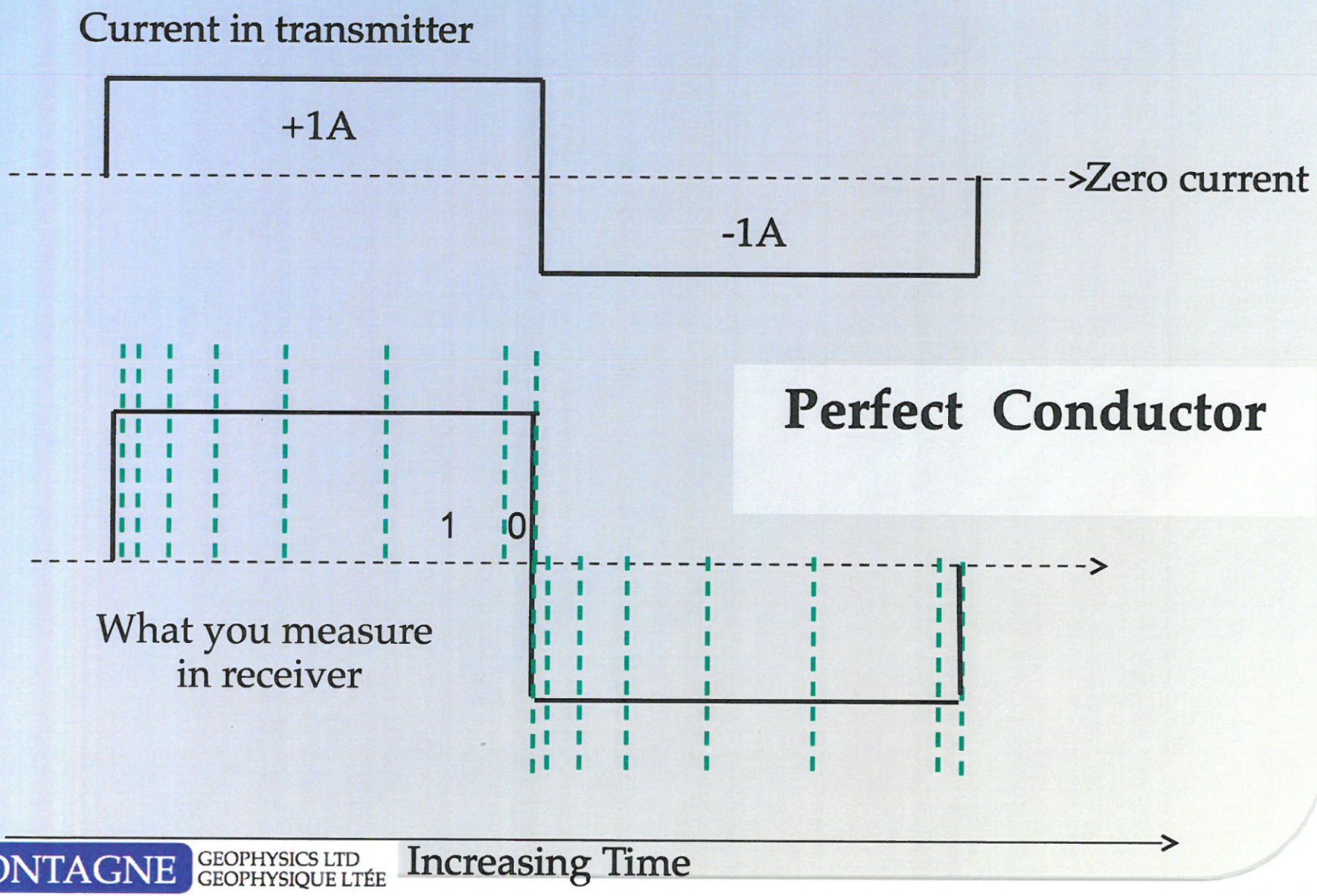
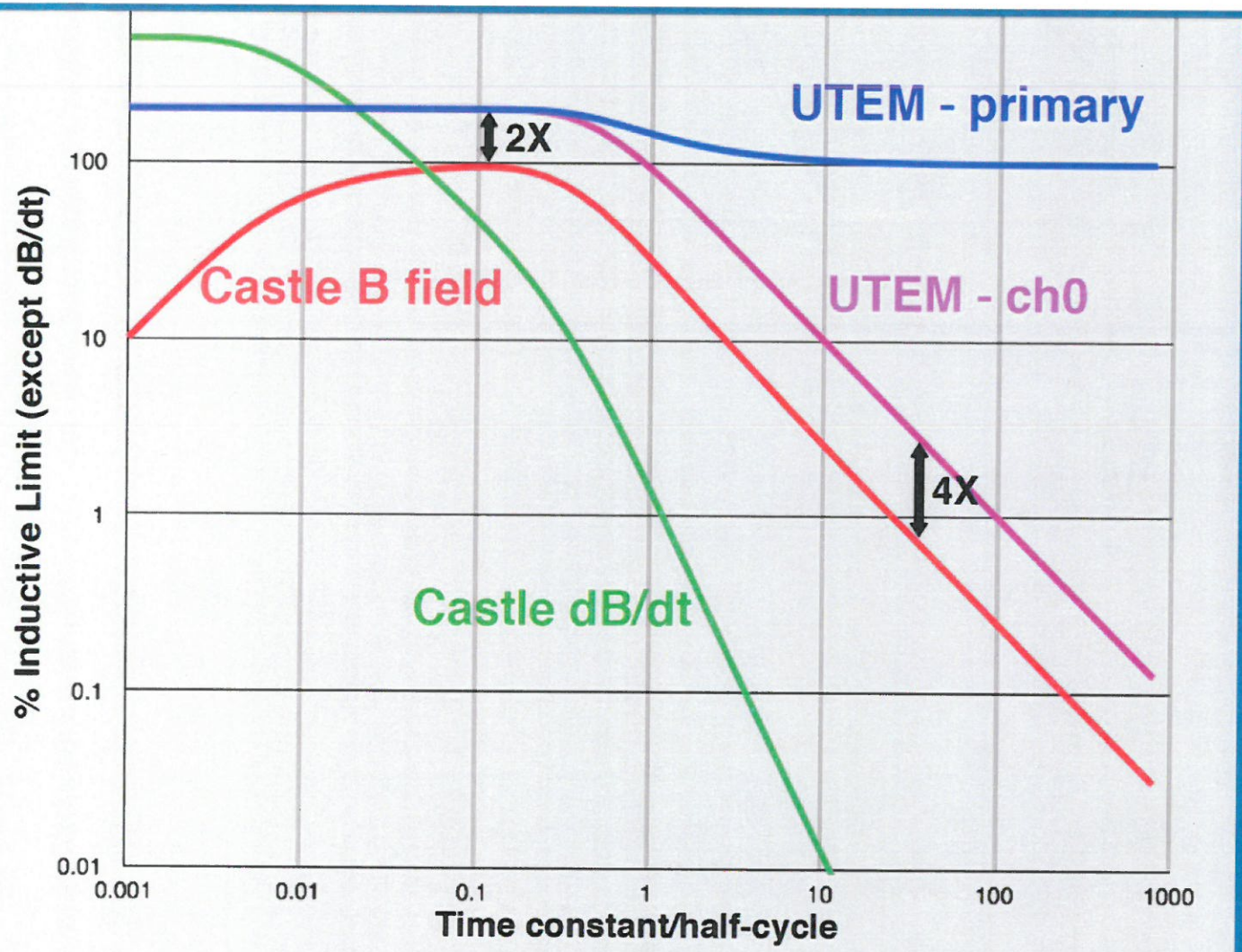
Note 'time-channels'



Note 'time-channels'



Sensitivity versus Decay time



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

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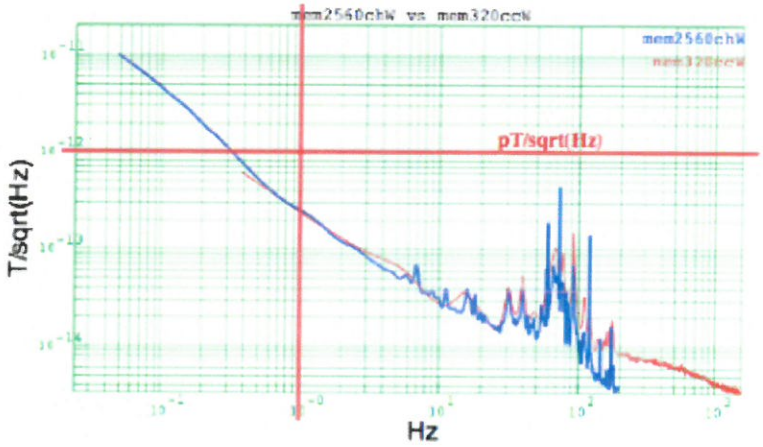
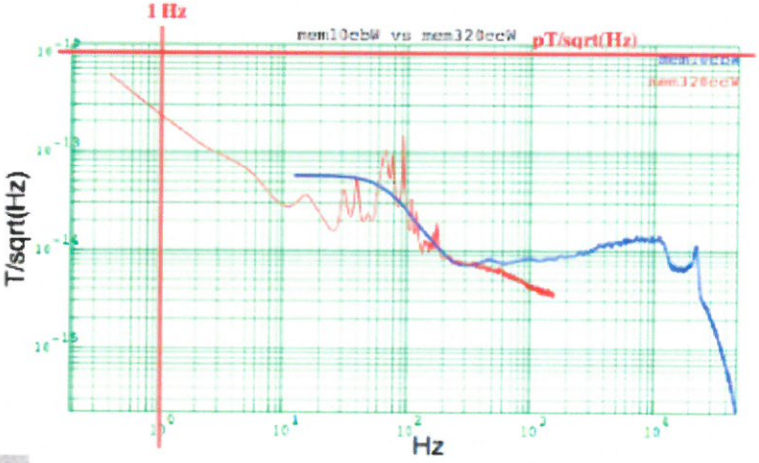
Table 1 – Notable developments			
Year	Version	EM Fields	Notes
1972	UTEM 1	dB/dt	**Thesis project**
1976	UTEM 2	dB/dt, E	**U of T / industry consortium**
1979	UTEM 3		**Commercialization of UTEM** **Establishment of LGL**
1981	UTEM 3	B (FB coil), E	PE/DC Level 1 **Cominco funding**
1983	BHUTEM 3	B axial	Borehole UTEM fibre optic link 2200m
1988	ISR CE	E	ISR capacitive electrodes
1989	BHUTEM 3H	B axial	Deep hole BH UTEM fibre optic link 3300m
1990	UTEM 3E	B, E	Level 4 PE/DC, 2 Hz master/slave Tx **LGL moved to 115 Grant Timmins Drive Kingston**
1996	BHUTEM 4 UTEM 4 Rx	3-axis B	3-axis feedback BH sensor, U4 Rx **Inco funding**
2002	UTEM 4 Tx		High power digital wave form Tx **Falconbridge/Cogema funding**
2010	LF ISR CE	E	Low frequency capacitive electrodes ISR imaging

Table 1 Continued			
Year	Version	EM Fields	Notes
2011	UTEM 5S	3-axis B	UTEM 5 3-axis surface feedback coil UTEM 5 Rx 3-Tx stacking
2013	UTEM 5 ISR	3-dipole E	UTEM 5 3-dipole E field
2014	UTEM 5M Tx		UTEM 5 transmitter M power
2015			**Purchase of 20 Binnington Court** **Drilling a borehole in the office**
2016	BHUTEM 5 probe	3-axis B	**Borehole UTEM probe only for HQ holes.** **Construction of zero field Gauss chamber**
2017	UTEM 5H Tx		UTEM 5 Transmitter H power
2019-2021	UTEM 5HP Tx		Build UTEM 5 HP Tx production / Pandemic / Probe loss.
2023			Certification process





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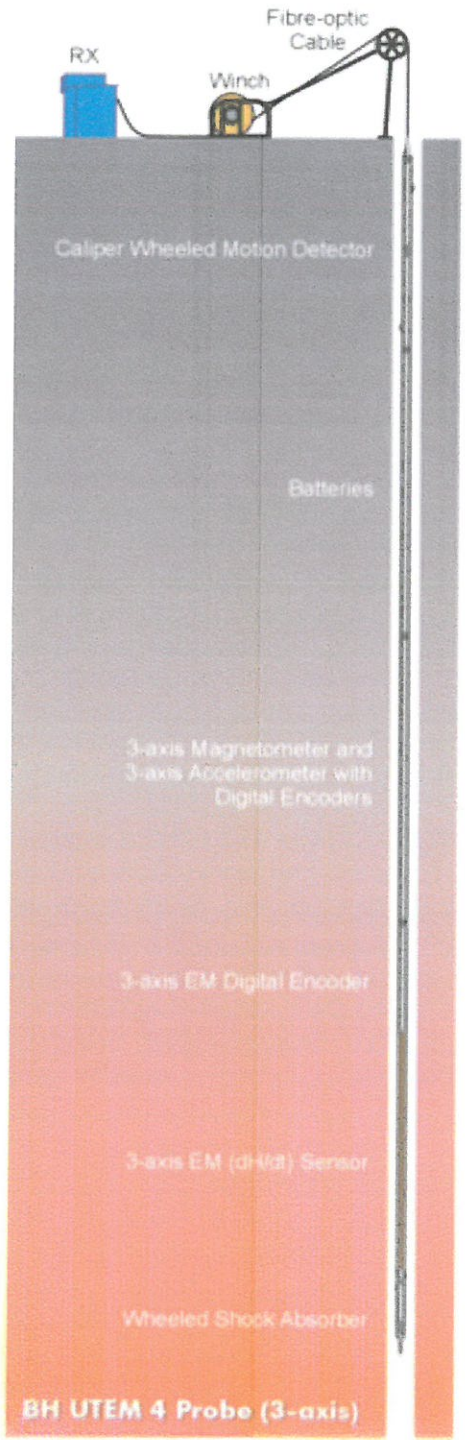
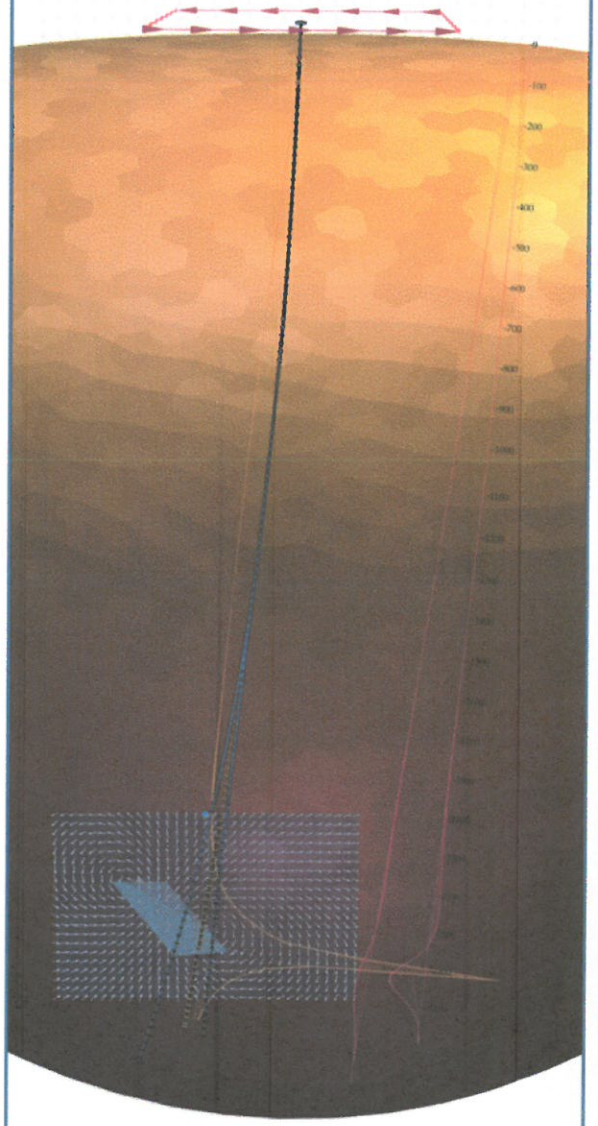


Custom Equipment for Specific Survey Challenges

BHUTEM

Multiloop EM Modelling

HTML5 Visualizer and Engine API



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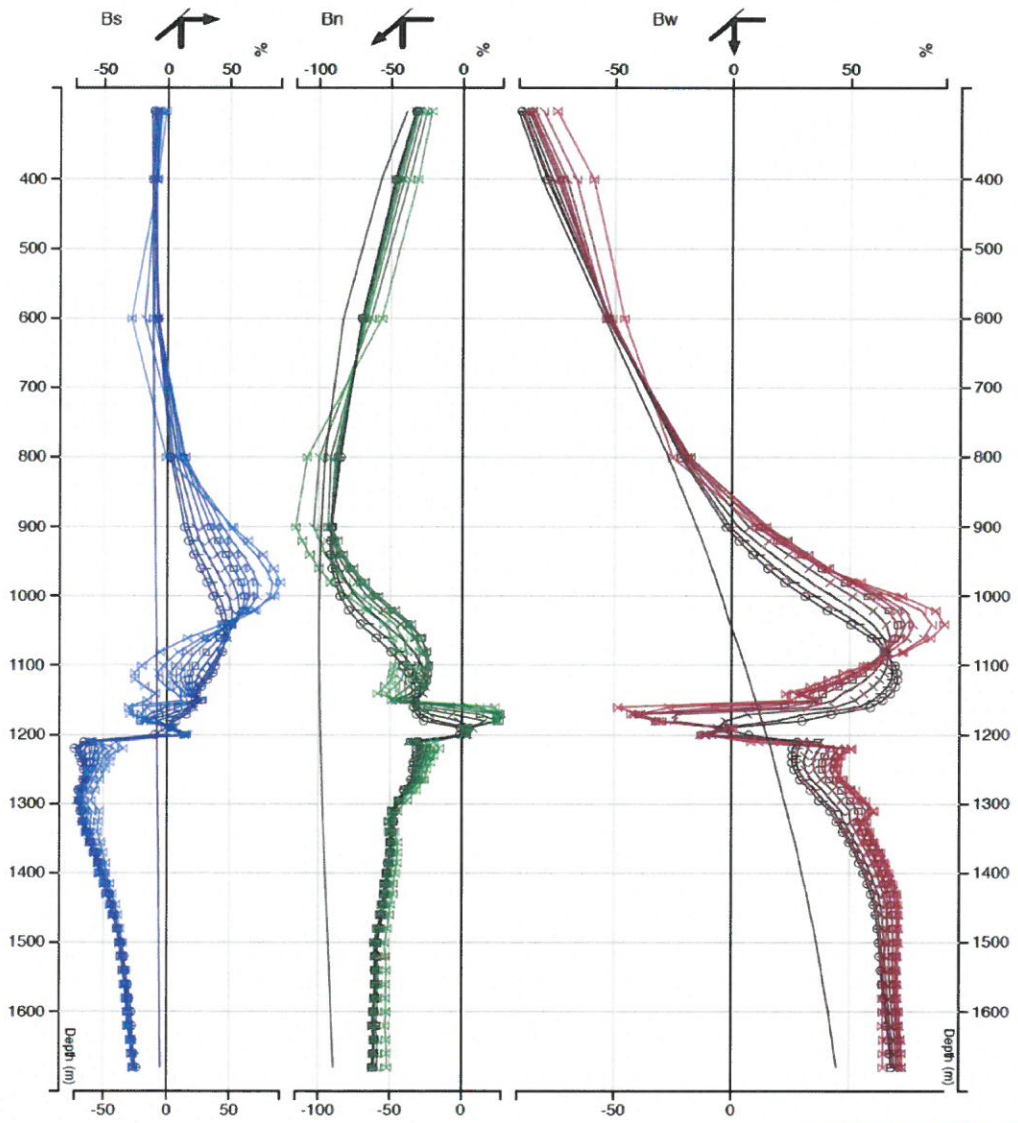
Sudbury BH data showing in-hole and off-hole responses using a base frequency of 4.6875Hz



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Successes

Discoveries attributed to using the UTEM system include:

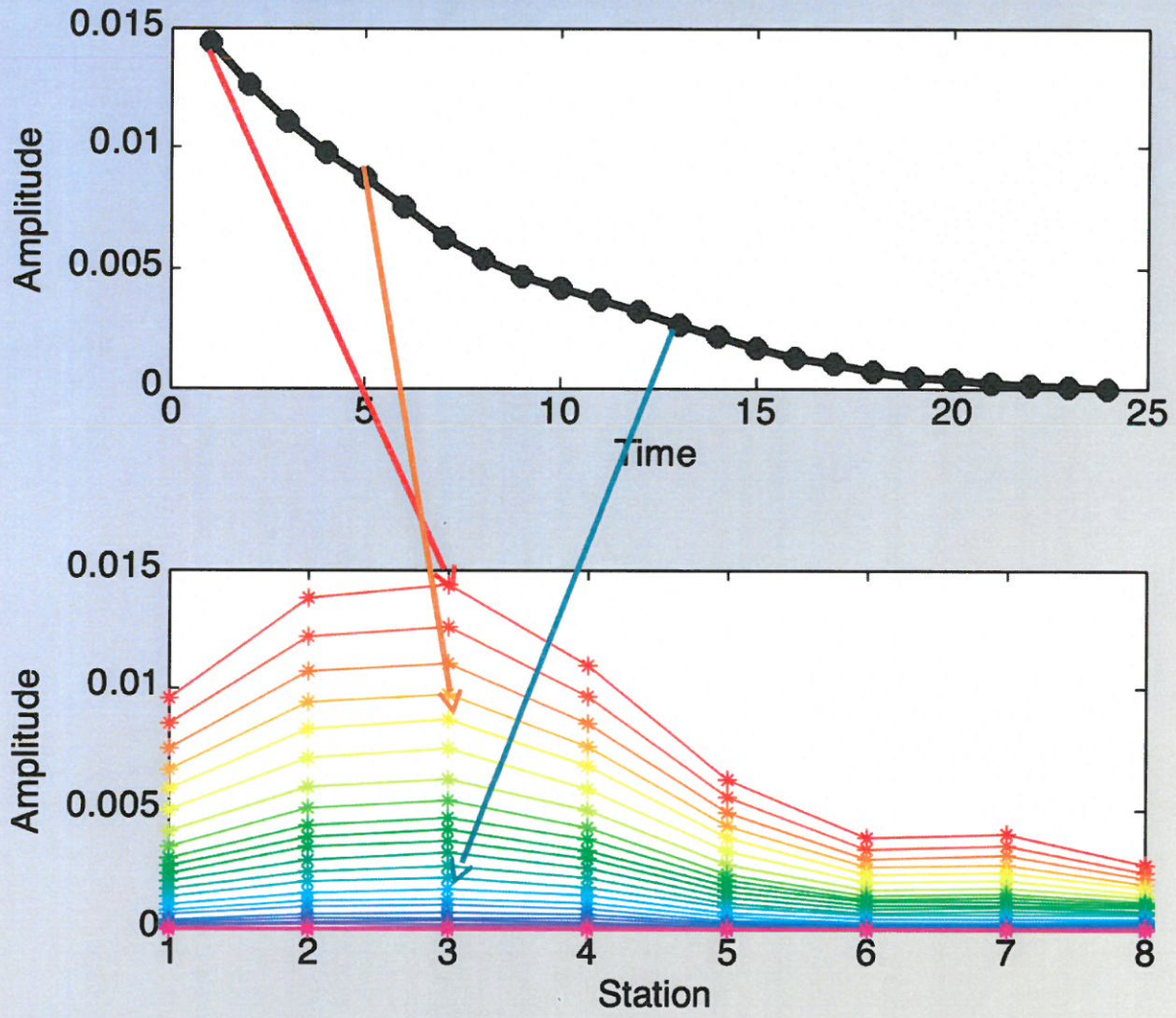
BHUTEM

Victoria Deposit - FNX Mining - KGHM
Nickel Rim South Mine – Glencore
Onaping Depth in Sudbury – Glencore/Vale
Norman West – Glencore - Sudbury
Victor Deep, in Sudbury – Vale
Totten Mine, Totten in Sudbury – Vale
Kelly Lake, in Sudbury – Vale
Coleman 153 – Vale Sudbury
McCreedy East Footwall in Sudbury – Vale
Podolsky Mine, in Sudbury – Vale
Morrison Deposit in Sudbury – FNX - KGHM
Levack West Footwall in Sudbury – FNX - KGHM

SURFACE

Heninga in NWT - St. Joe Minerals
Kudzu Ze Kayah in Yukon - Cominco – Teck
Neves Corvo – Lombador Deposit - Pyrite Belt in Portugal – Somincor - Lundin
Hellyer in Tasmania, Australia - Aberfoyle - Cominco – Teck

Decay curve versus Profile

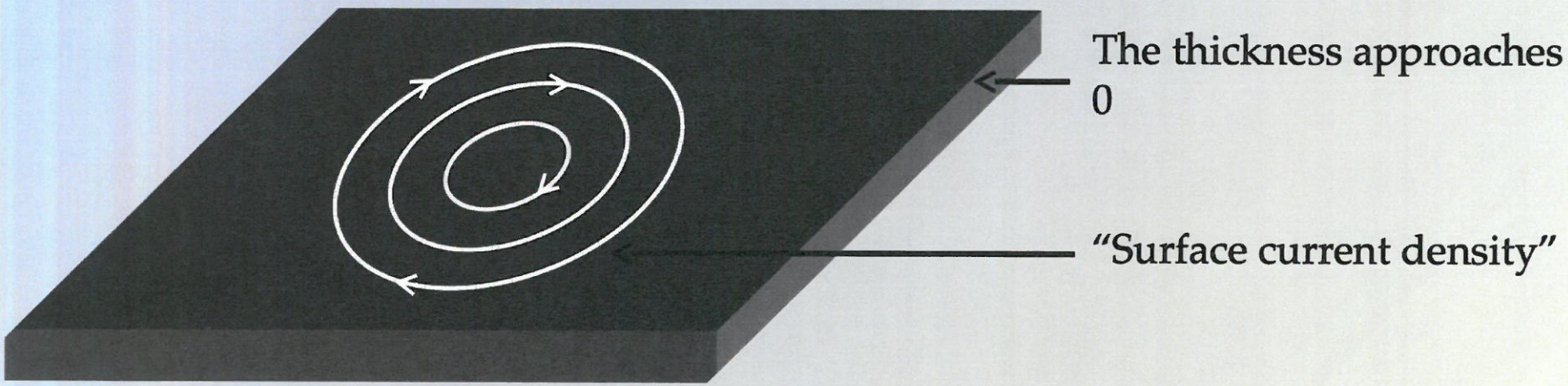


Thin sheet approximation

Simplify when the geology allows it.

The thin sheet approximation:

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



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The thin sheet approximation:

- Many mineral deposits can be approximated as thin sheets.

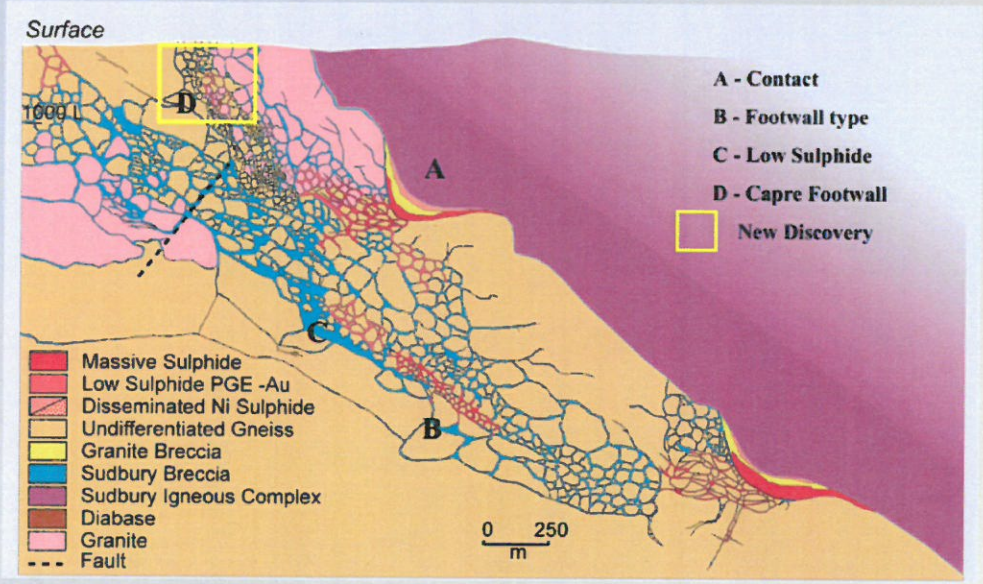

Image from Stewart and Lightfoot

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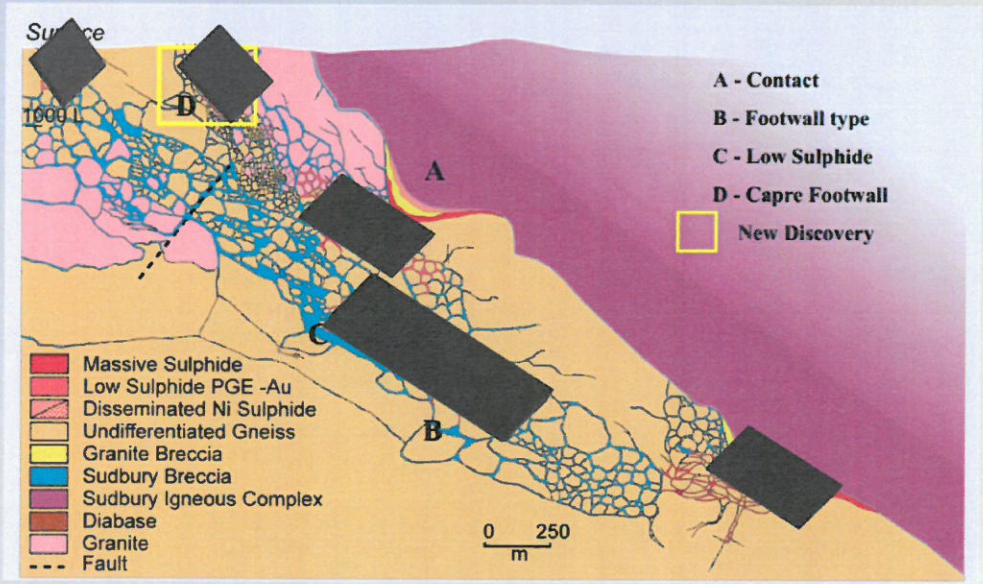

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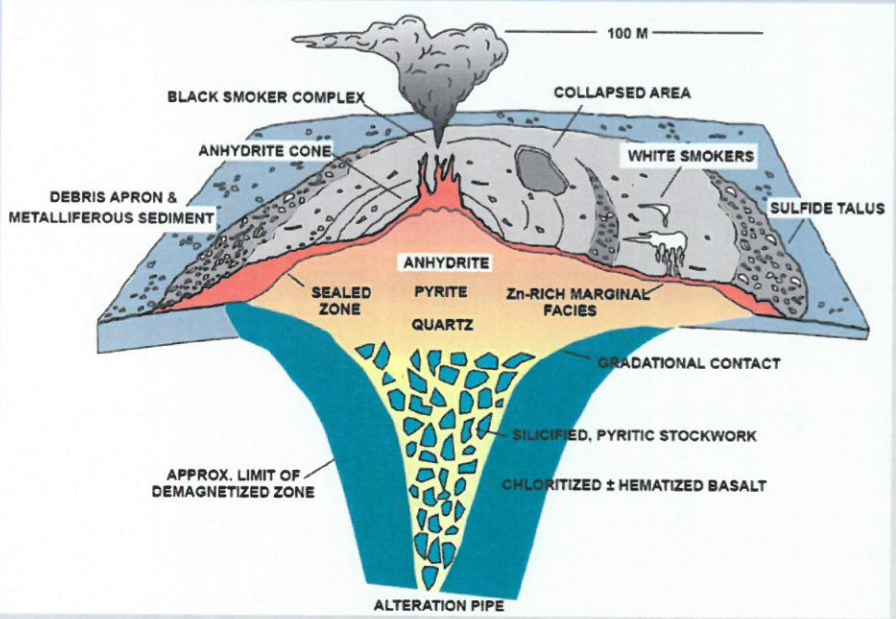

Image from Stewart and Lightfoot 2010

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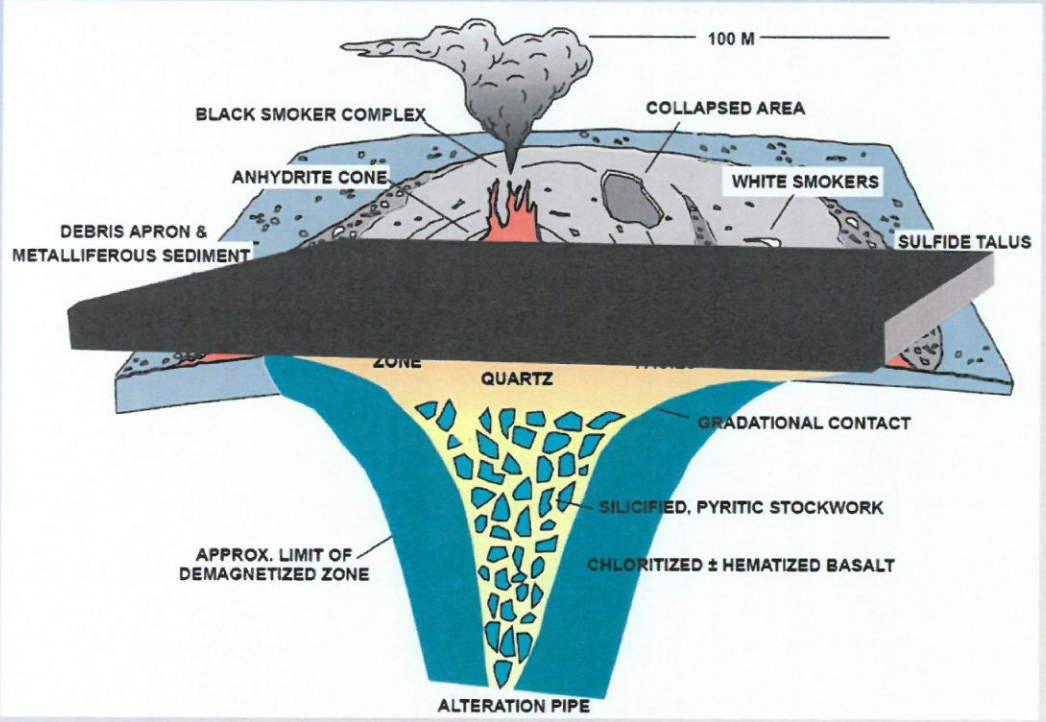


Parametric models - sphere

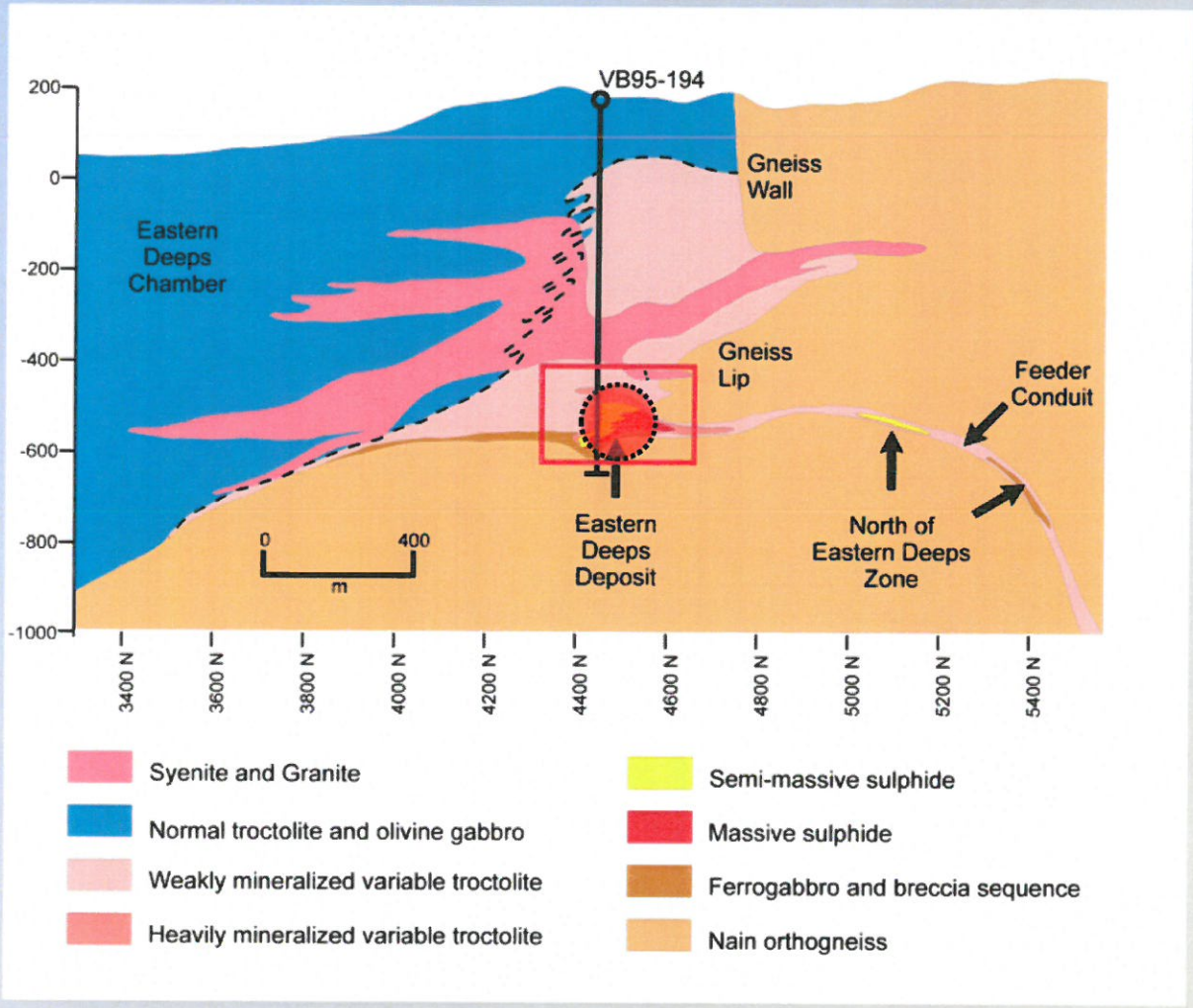
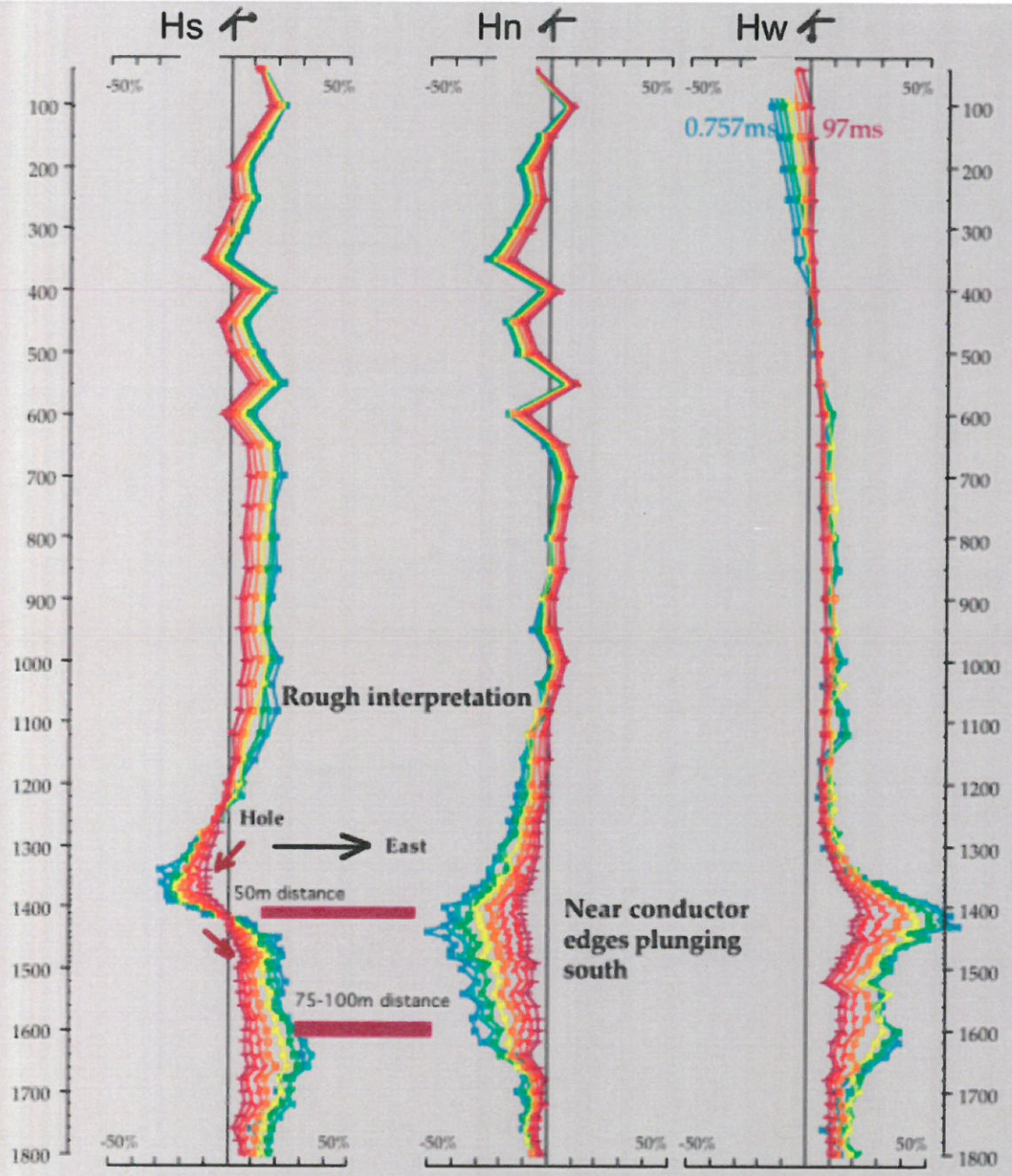


Image from Lightfoot 2007



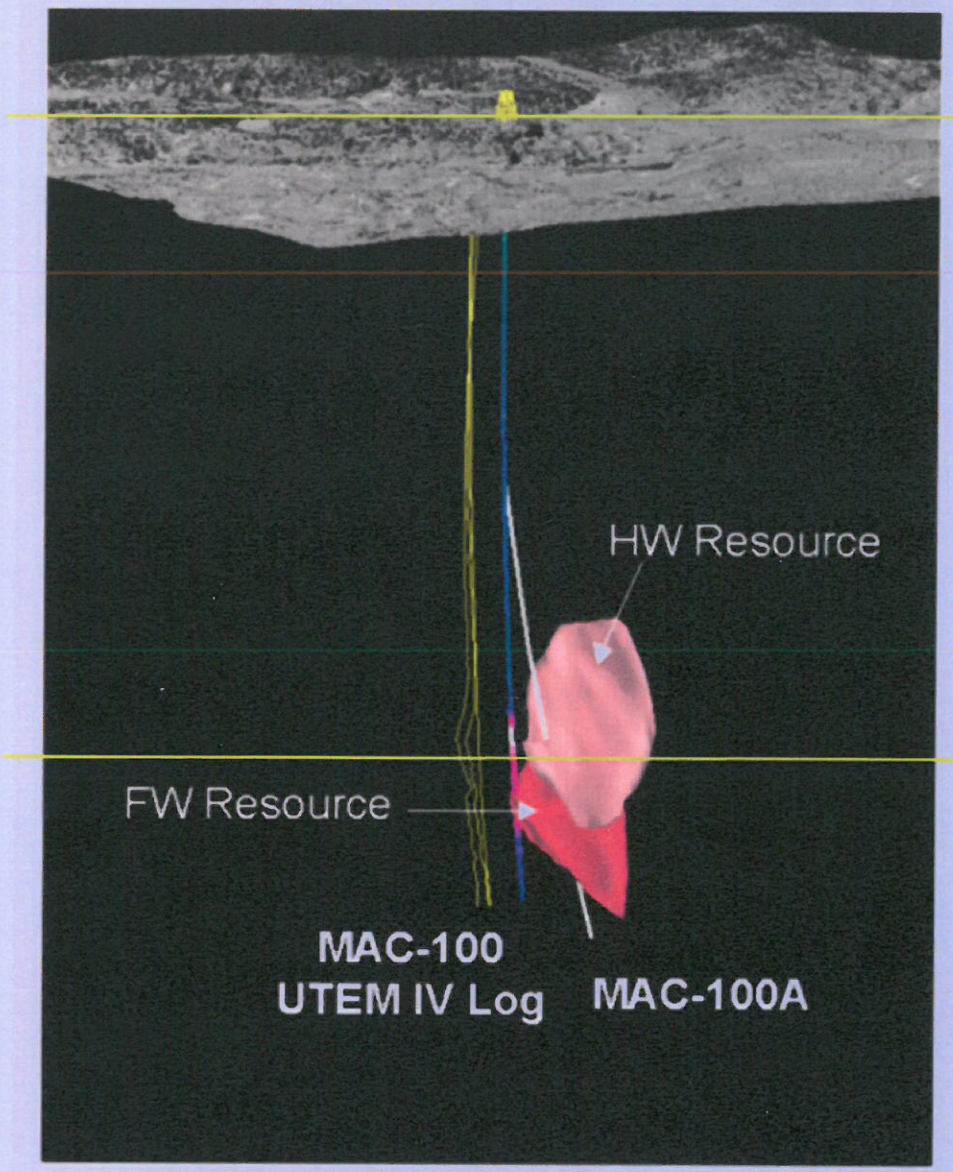
Nickel Rim South

Hole Mac-100

data oriented using

rotated section azimuth

S=90°, N=180°



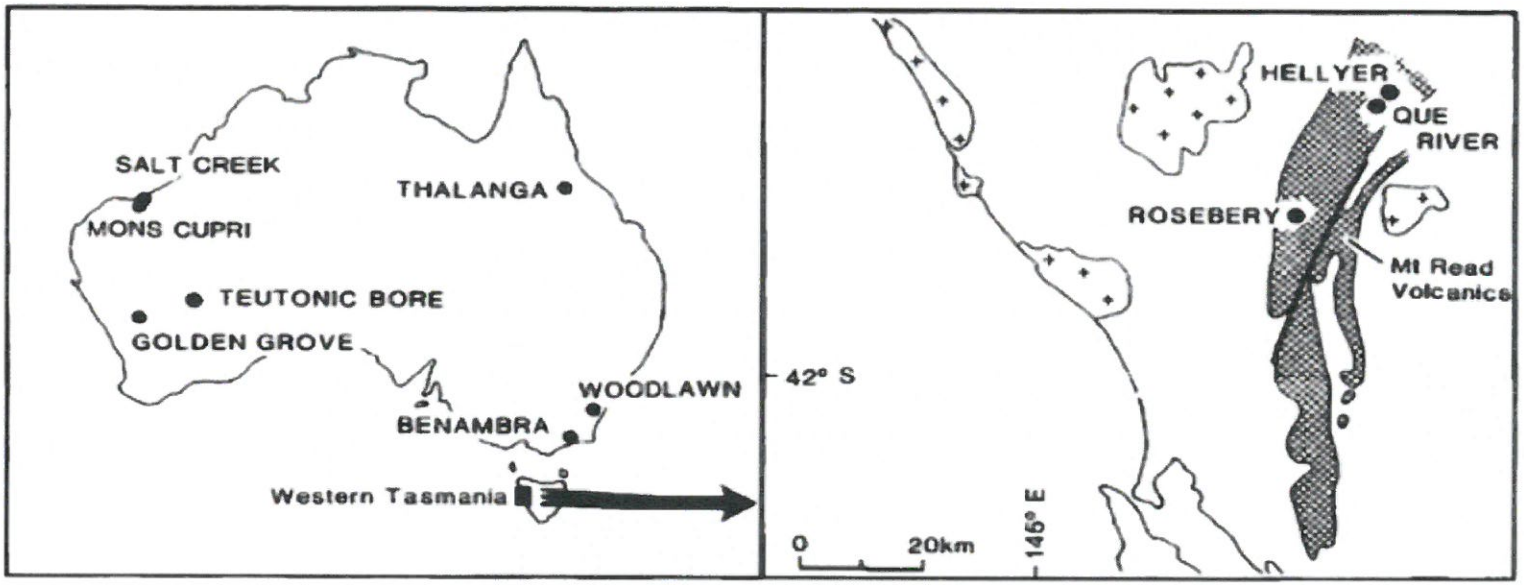
Nickel Rim South discoveries as currently defined by drilling

500m

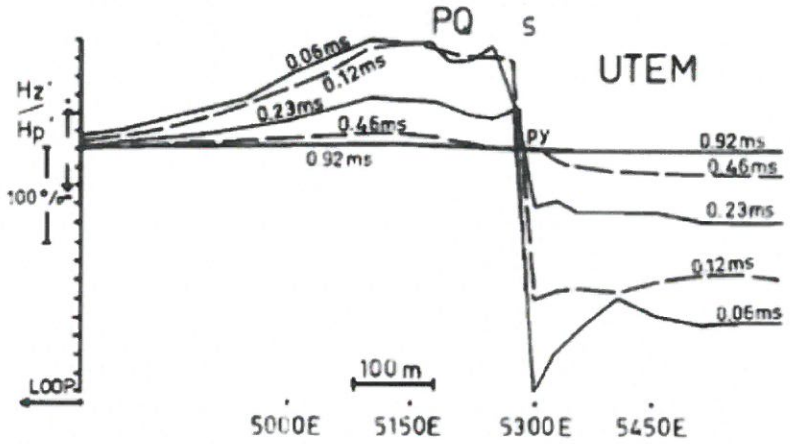
500m

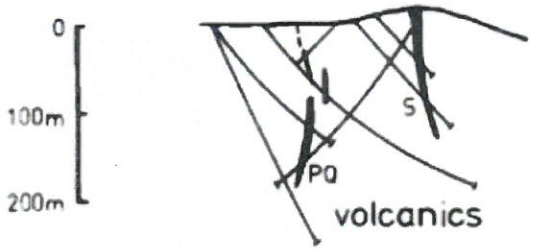
Drawing courtesy of Xstrata Nickel

Que River, Tasmania Case Study



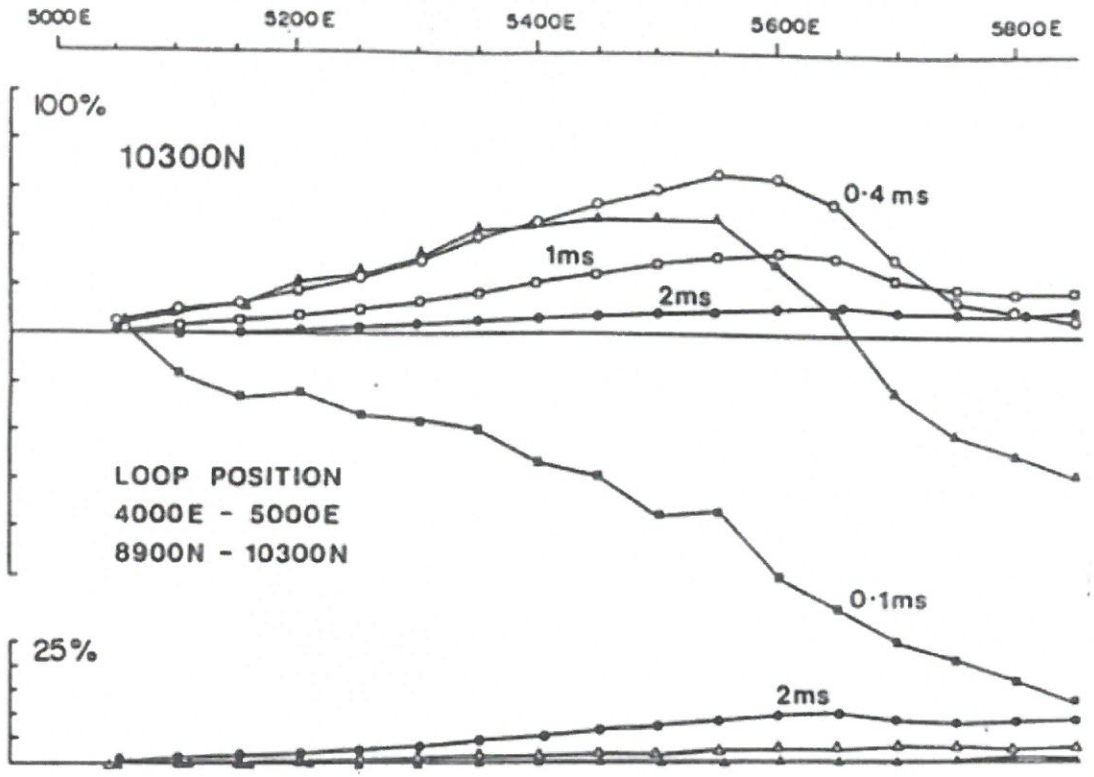
Que River, Tasmania Case Study





Deposit	Zone	Conductance	Strike	Length	Thickness	Depth	Dip
		S	m	m	Max m	m	
Que River	PQ lens	20	150	600	9	100	85

Hellyer, Tasmania Case Study



Deposit	Zone	Conductance	Strike	Length	Thickness	Depth	Dip
		S	m	m	Max m	m	
Hellyer		50	750	200	30	100	0

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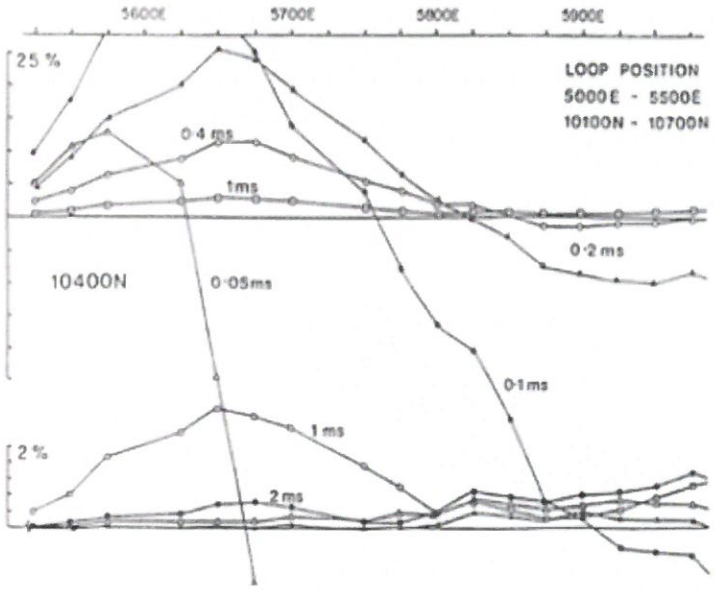
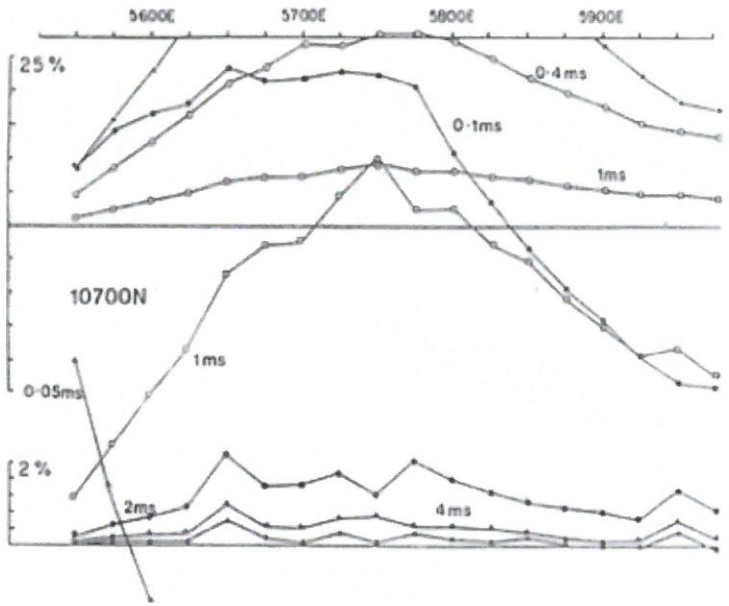
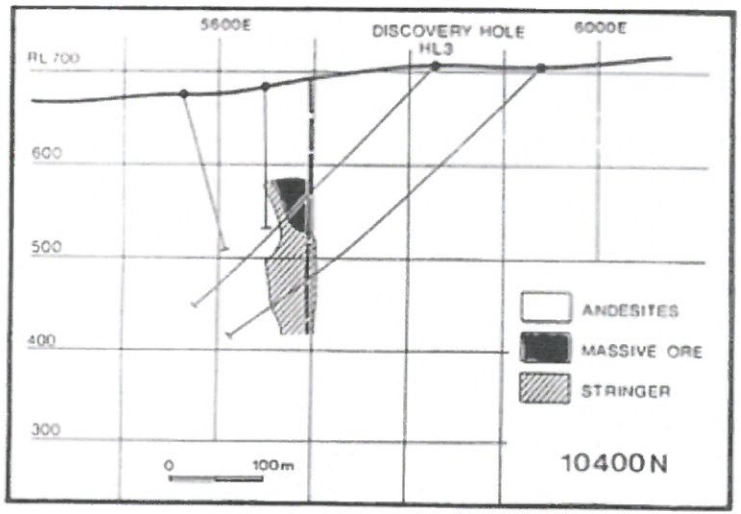
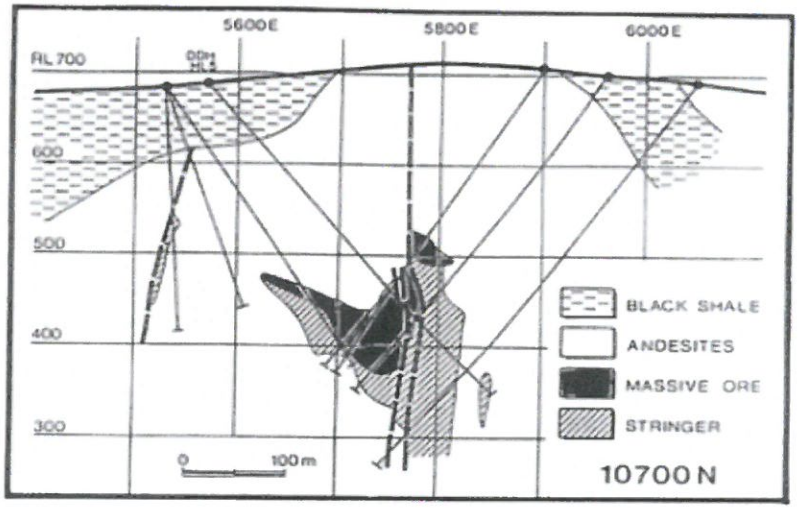
Hellyer, Tasmania Case Study









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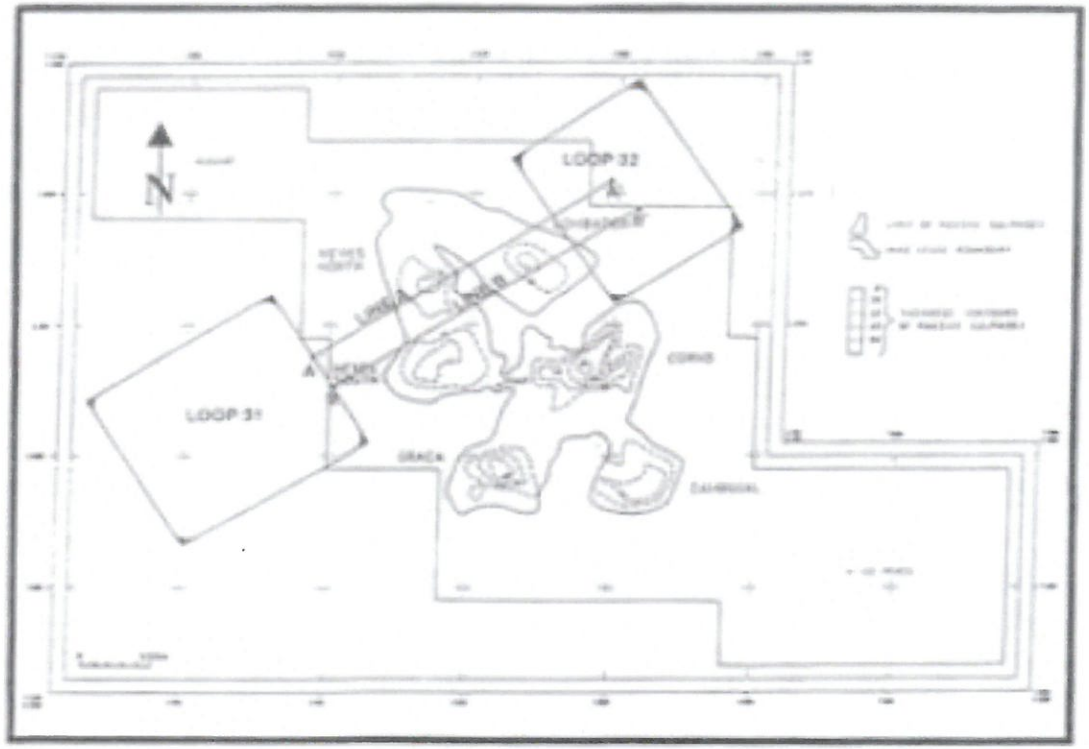
Neves Corvo, Portugal Case Study

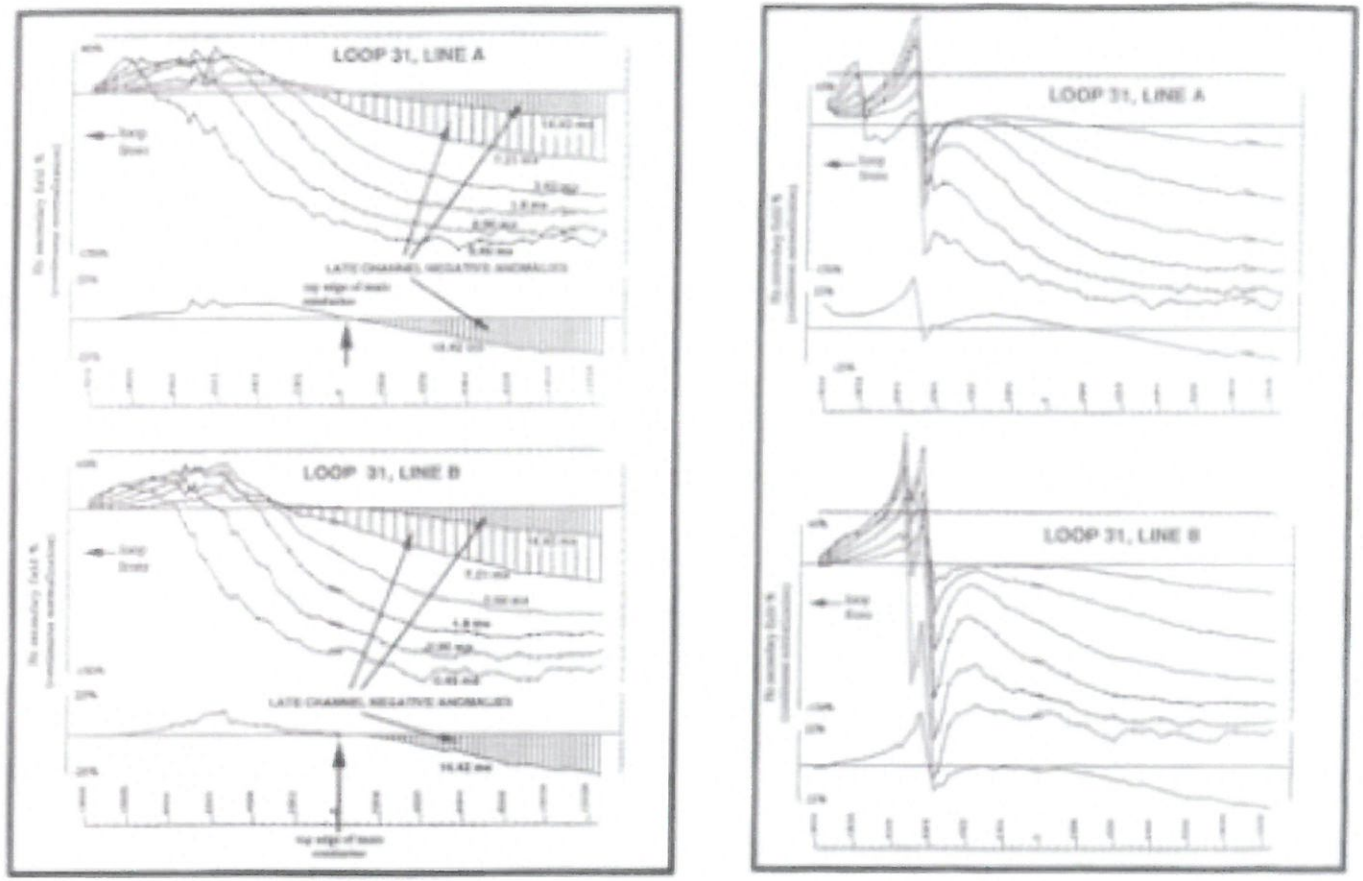
Figure 1: Neves Corvo location map.



Neves Corvo in Portugal - Incisor - Lundin Mining

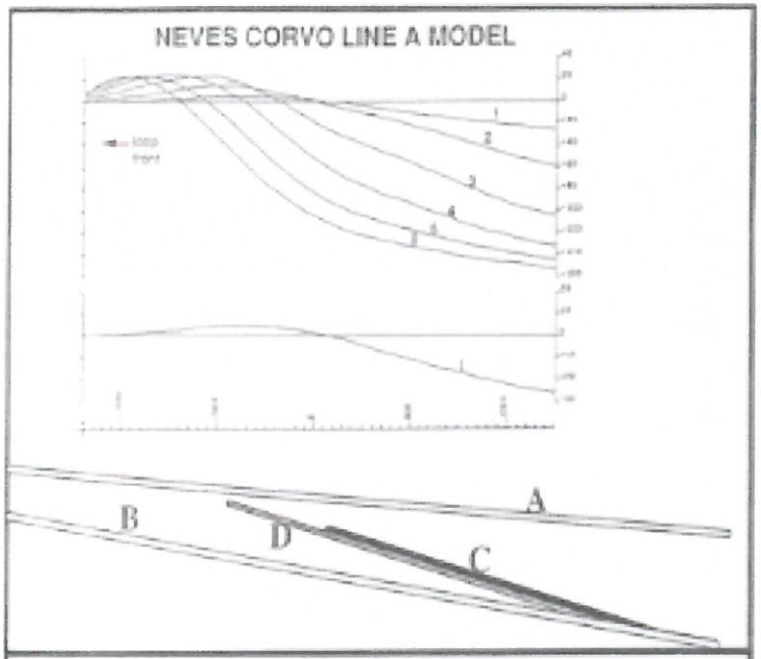
Two lines, 275m apart, were recorded from two separate loops going over the Neves North deposit (this slide). The data from Loop 31 provided the best results. Large amplitude cultural anomalies due to power lines are clearly evident (next slide, right). The cultural anomalies were stripped from the data providing good quality data for interpretation (next slide, left) Neves North was clearly seen as was a new anomaly down dip. This anomaly identified the Lombador deposit just prior to drilling. Despite the cultural anomalies, and the presence of conductive layers above and below the target, UTEM had no difficulty with seeing the new target at a depth >600m. Thin plate modelling of the UTEM field data using MultiLoop 2 (see forward 2 slides) provided accurate measurements of the dip, depth extent and strike extent of the ore body.

Neves Corvo, Portugal Case Study



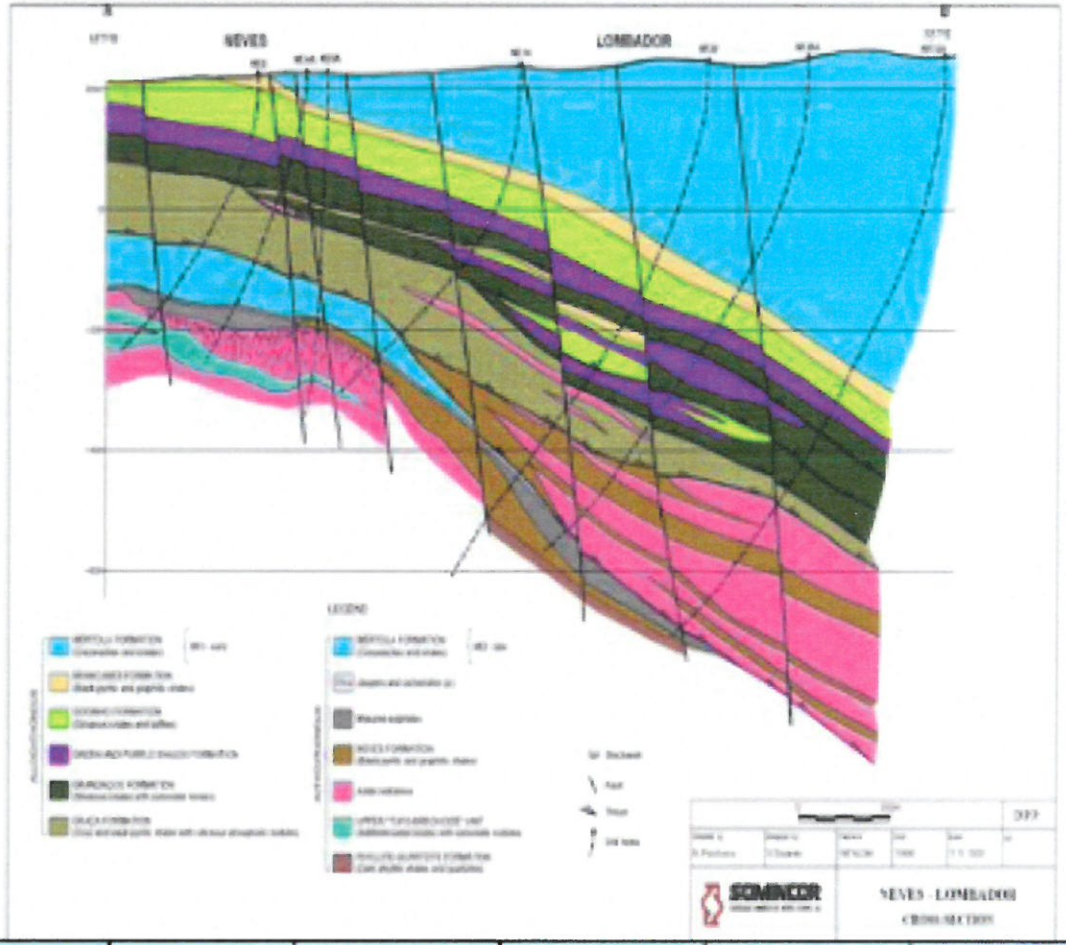
Right Image shows large amplitude cultural anomalies due to power lines which needed to be stripped from the data. Left image shows interpreted data clearly identifying the Lombador zone prior to drilling.

Neves Corvo, Portugal Case Study



Conductor Parameters

A:	conductive cover layer dip = 5 degrees conductance = 1.5 siemens strike extent = 800m dip extent = 600m	C:	location = 60N depth = 450m dip = 16 degrees conductance = 125 siemens strike extent = 800m dip extent = 1800m
B:	conductive cover layer dip = 9 degrees conductance = 5 siemens strike extent = 800m dip extent = 800m	D:	location = 450 S depth = 320m dip = 16 degrees conductance = 65 siemens strike extent = 1100m dip extent = 2100m



Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Neves Corvo	Neves North	65S	1200m	700m	55m	300-400m	0-35°
	Lombador	125S	1600m	1400m	15m	600-800m	35° (NE)

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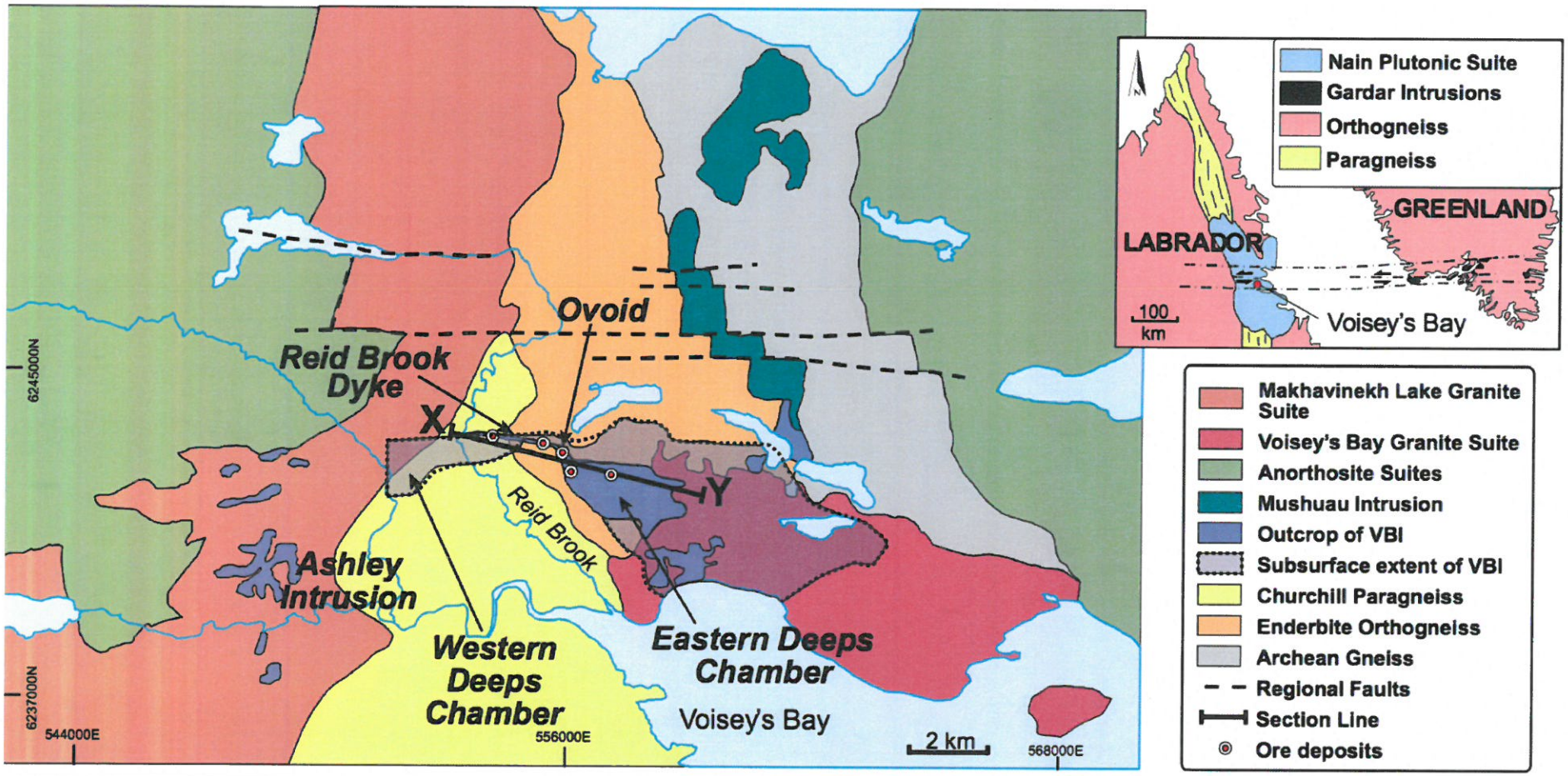
Geology of the Voisey's Bay Deposit



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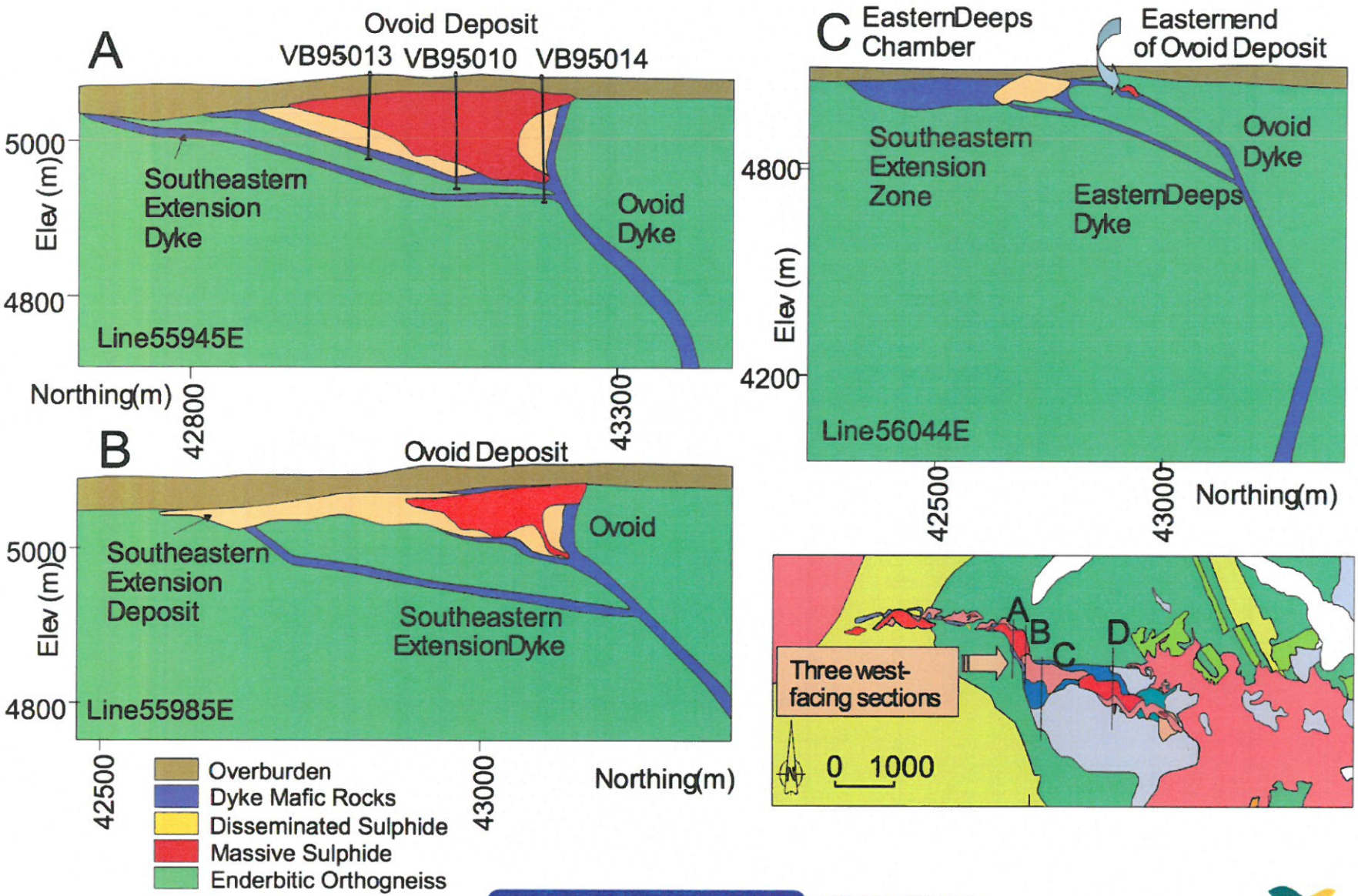
Geological relationships in the Ovoid



ightfoot et al (2011)

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VALE

Massive Sulphide Ore – The Ovoid

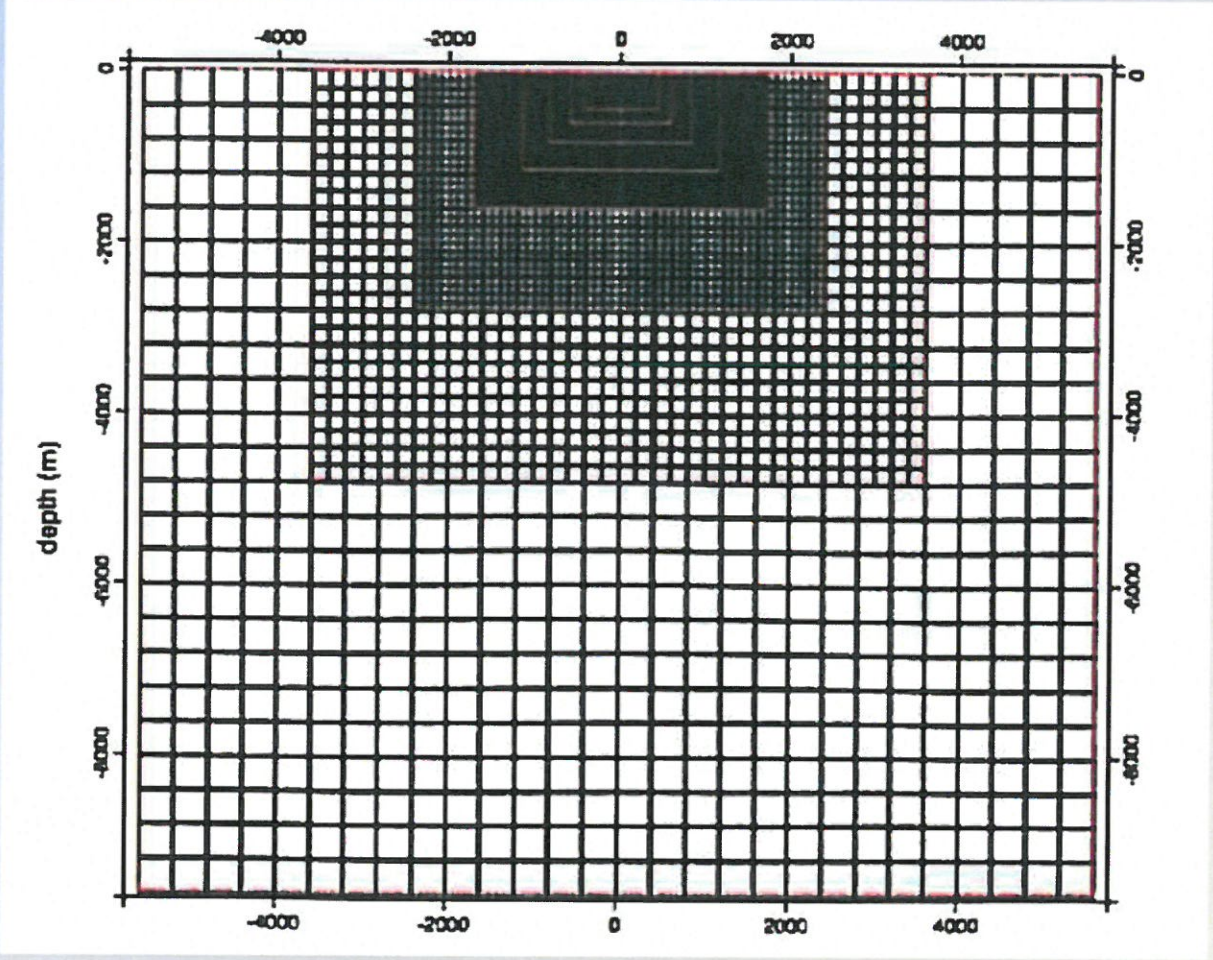
70% Pyrrhotite
15% Pentlandite
10% Chalcopyrite

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

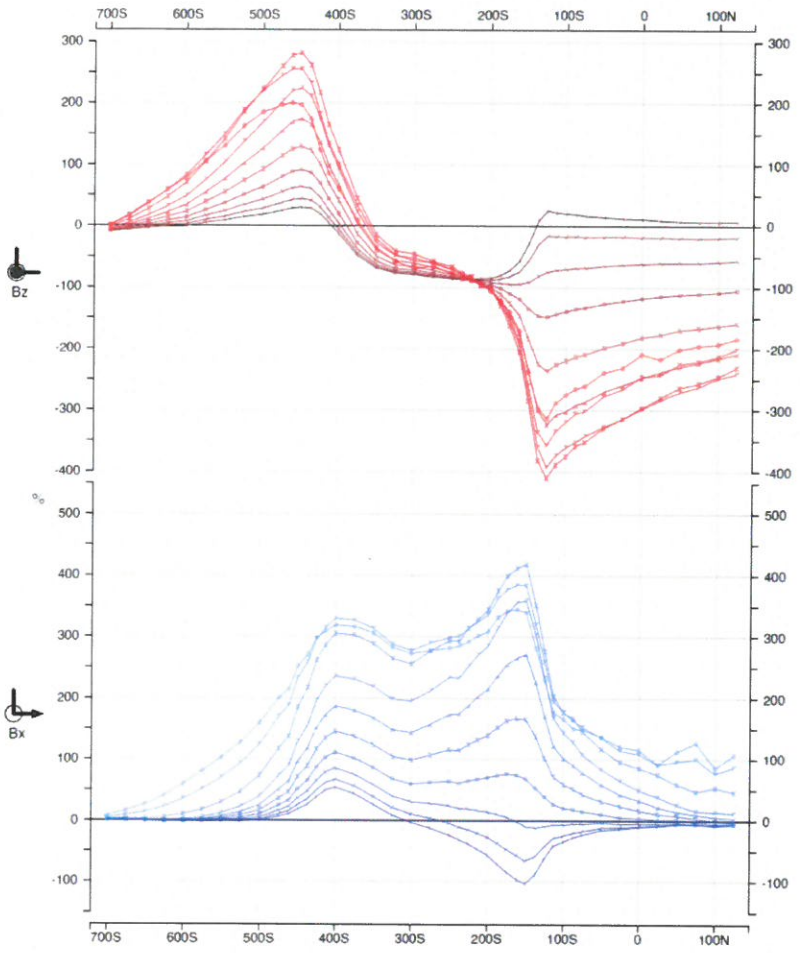
MGEM – Full MultiGrid Finite Difference Method Forward Modelling

X-section of the multigrid expanding below the earth's surface.
Mesh boundaries shown in Red

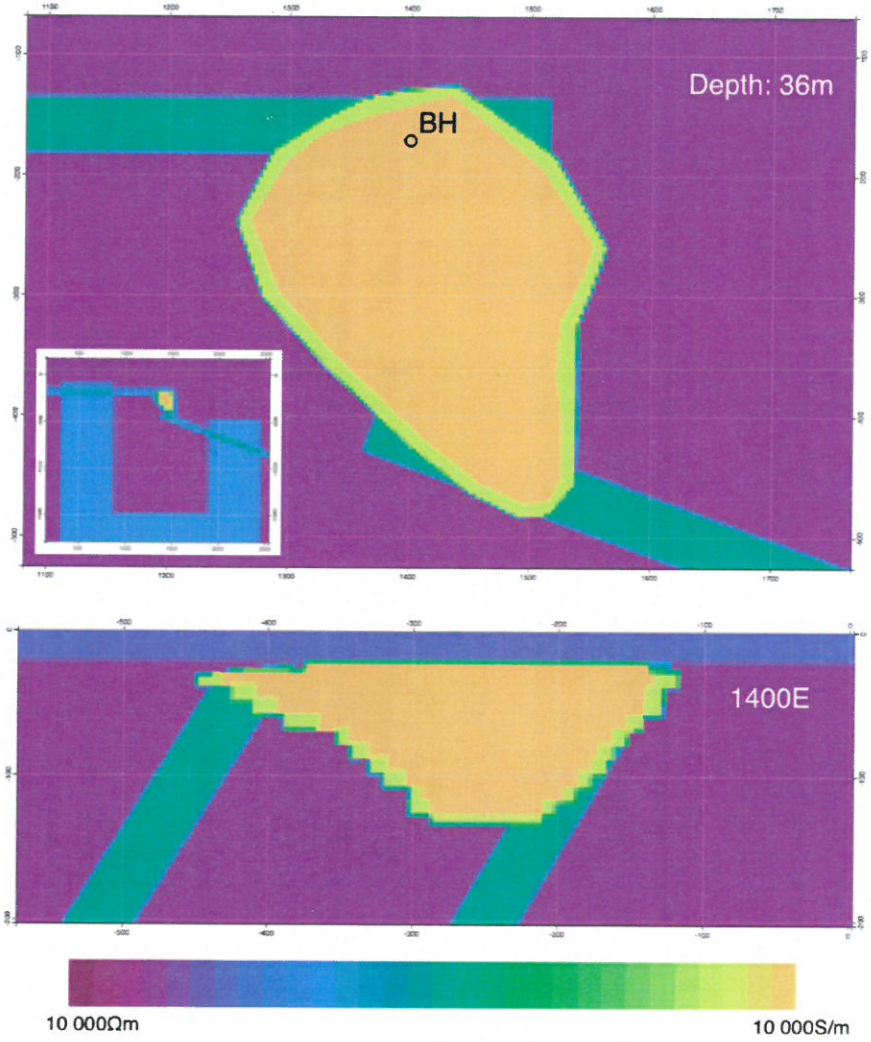


EM modelling

EM response of geology



'Geology'



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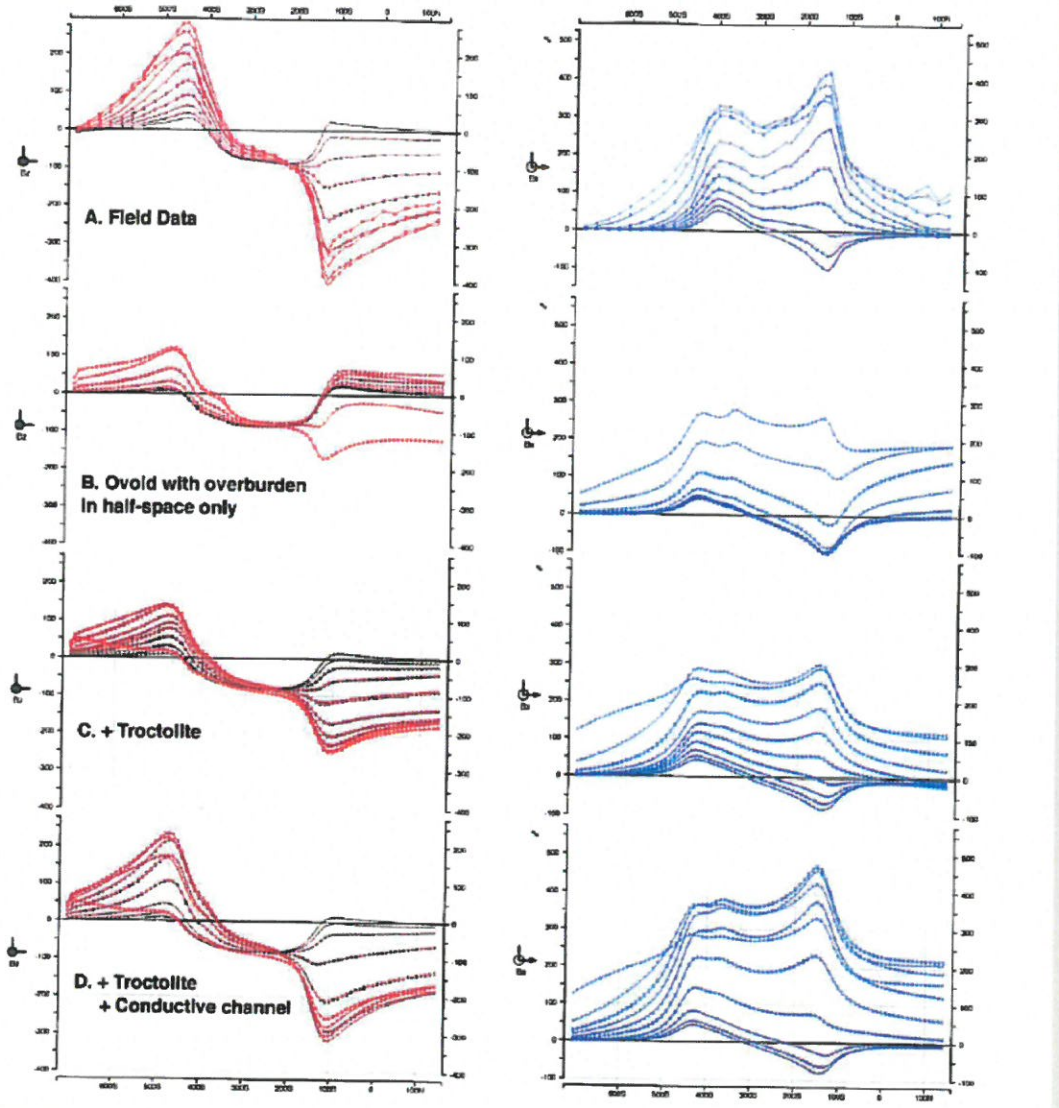
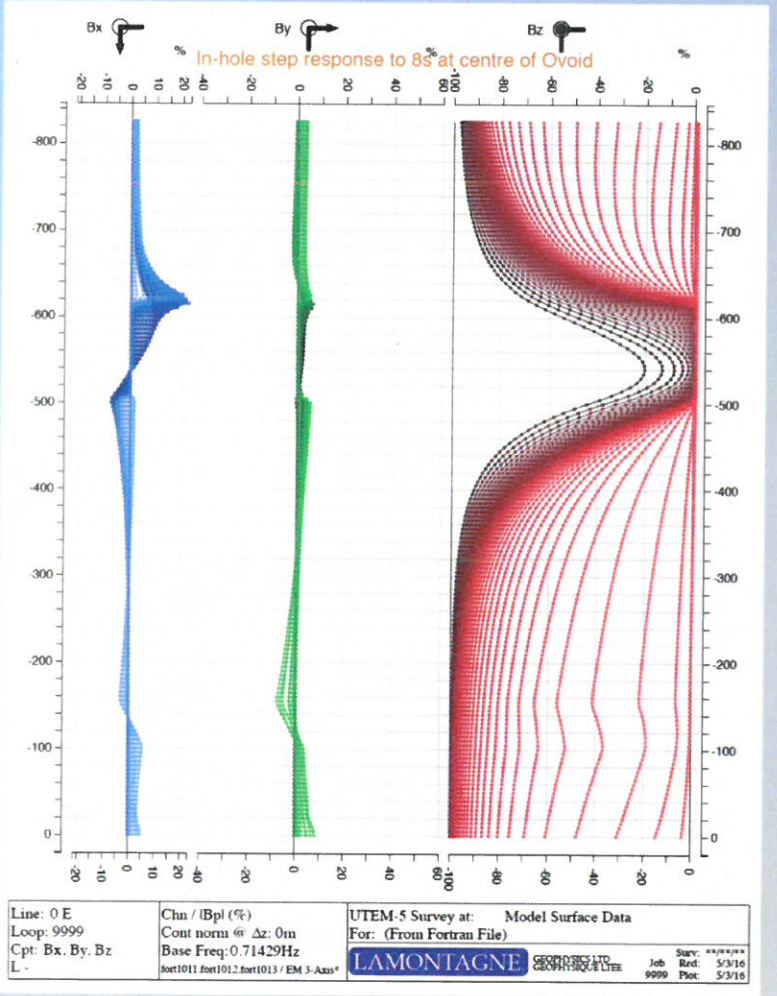
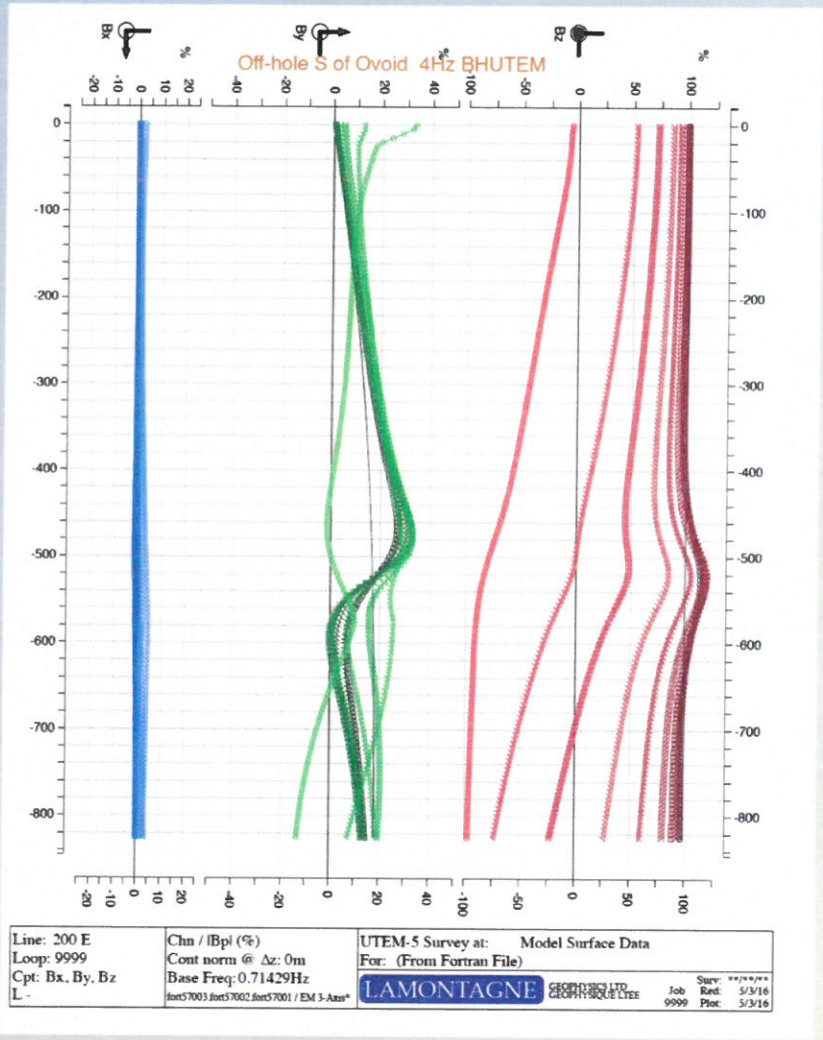

A. Field Data
B. Ovoid with overburden
in half-space only
C. + Troctolite
D. + Troctolite
+ Conductive channel

Ovoid modelled drilling



Predicted in-hole response in Centre of Ovoid



Predicted off-hole response South of the Ovoid

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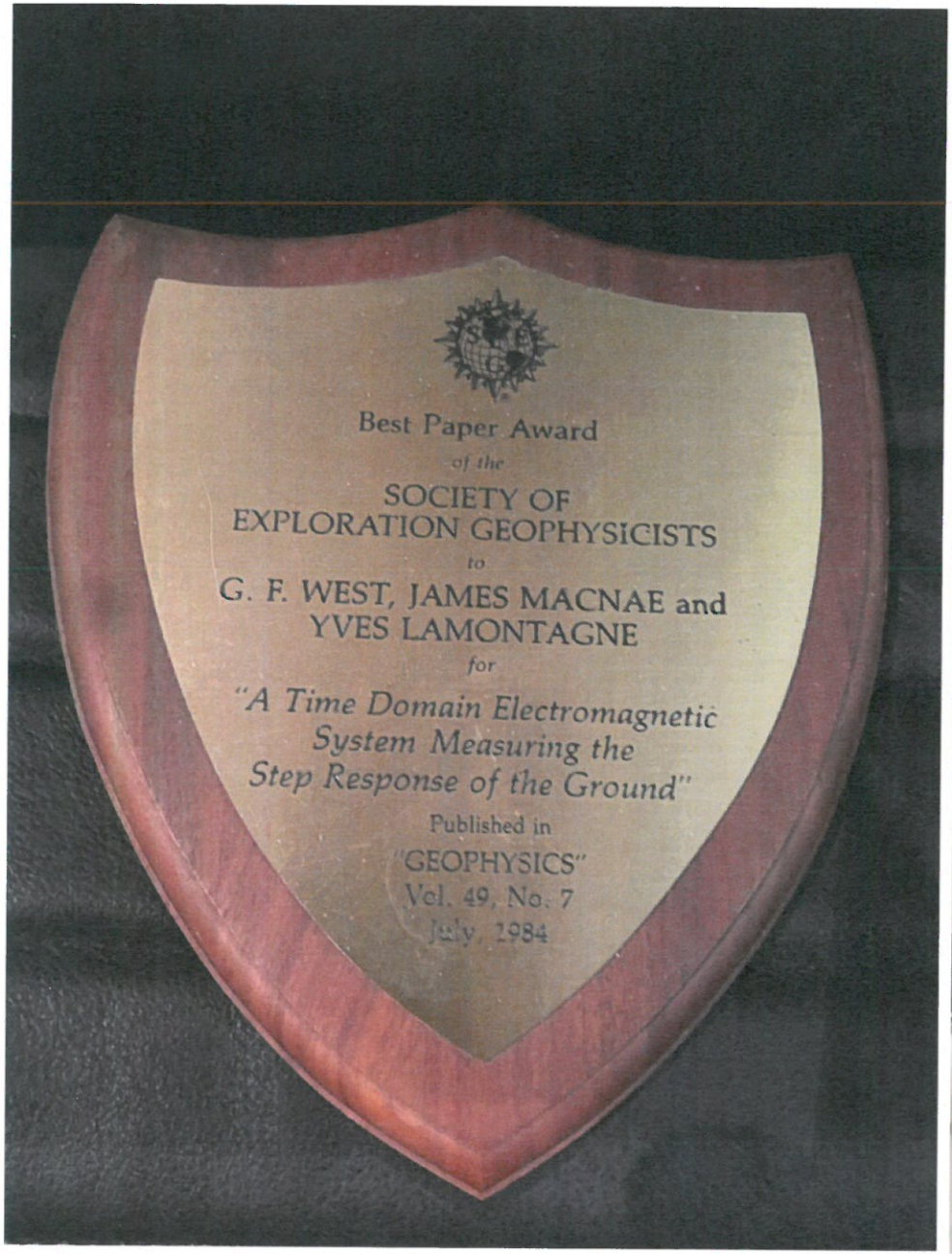

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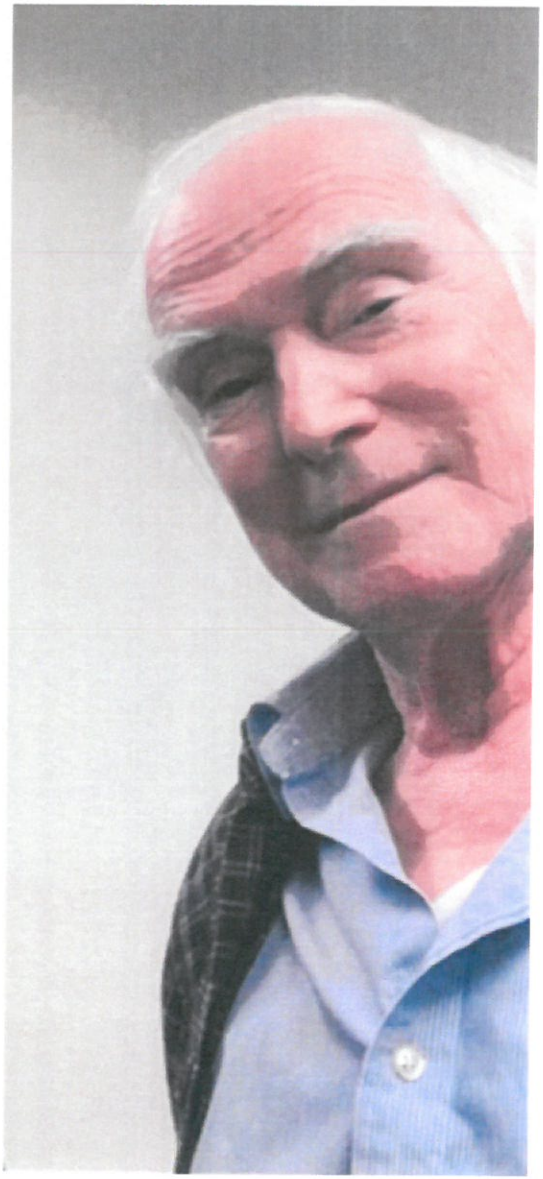

Yves in the office December 20th 2022

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