Review of UTEM Measurements from VHMS Discoveries and Test Surveys with Implications for Future Exploration

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Abstract

VHMS deposits are high value base metal deposits that become even more enticing with the addition of precious metals such as gold. Historically, EM methods have been the main tool used in the search for these deposits.

Favoured terrains, such as Archean greenstone belts, have had numerous single extensive AEM surveys and surface EM surveys completed yielding a single major discovery (Lalor) in the last 30 years. These AEM surveys generated tens of thousands of anomalies with no clear differentiating EM features.

Of particular concern is the perceived gap in the depth of discovery (50-200m) that was well described by Witherley and Allard (SEG 2010) even though modern AEM systems have a theoretical detection limit greater than 200m. Several possible reasons have been suggested for this. I will try to shed some light on the mystery drawing on the historical survey data from eight UTEM case studies and from 3D EM modelling results.

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Presentation Outline

What are VHMS deposits?

UTEM system

Uniform Sensitivity

VHMS Case Histories using UTEM

Summary Table

Lack of discovery

Explaining the gap

MGEM modelling can explain part of the problem

Discussion

Acknowledgements

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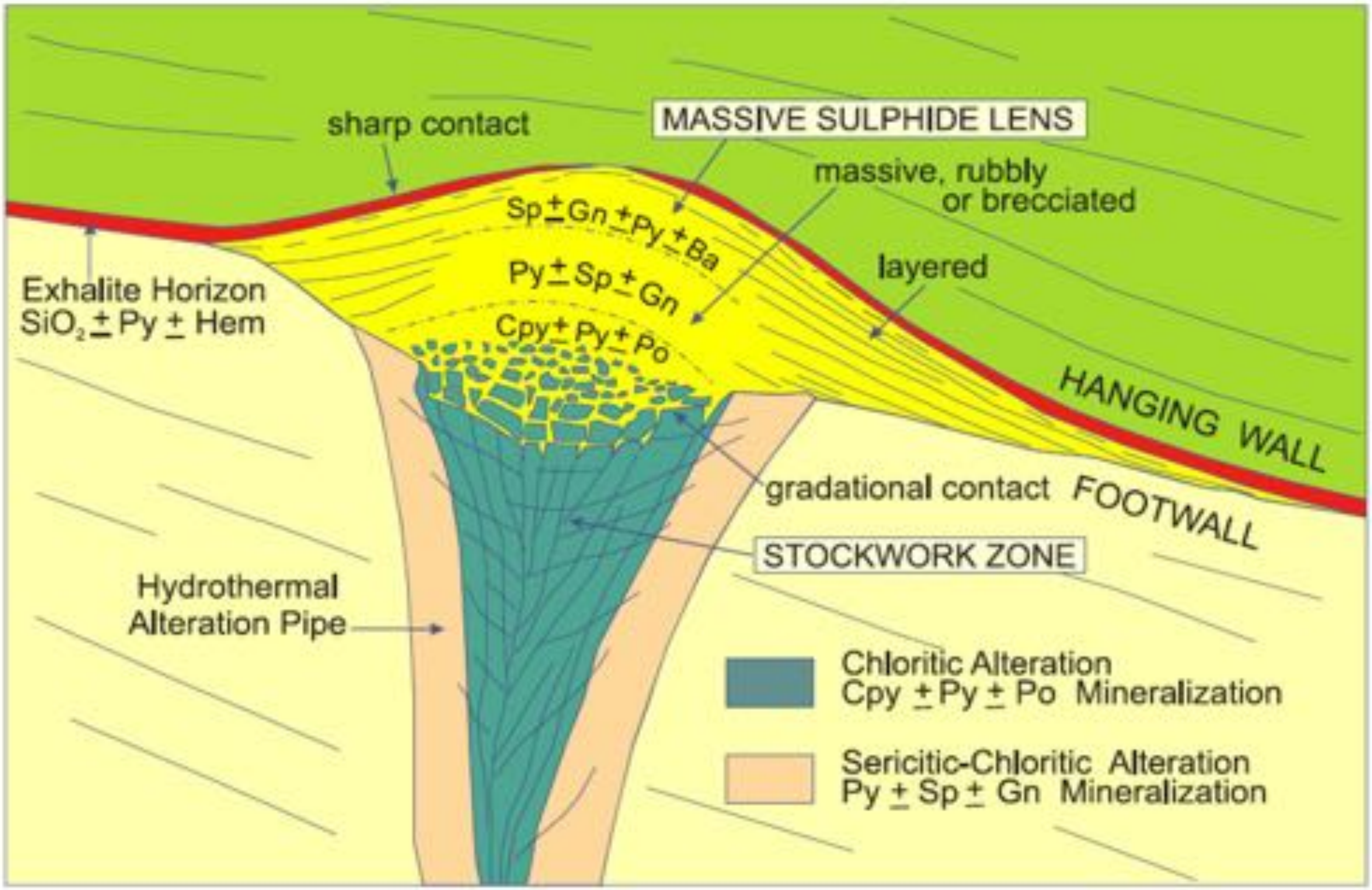
Idealized Cross-Section of a Volcanic Hosted Massive Sulphide Deposit



After Lydon, 1984

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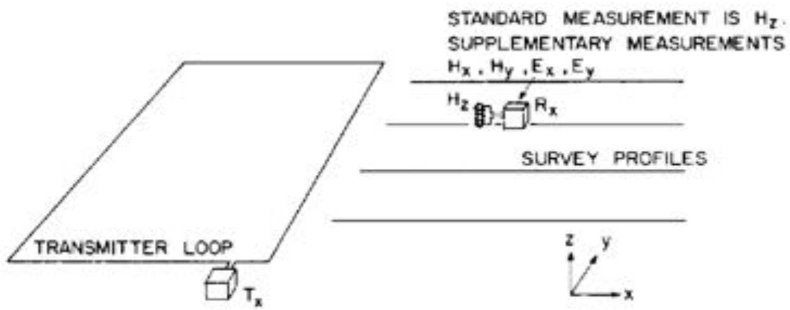
UTEM system
University of Toronto Electro-Magnetics system

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 UTEM3 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 UTEM5.

The UTEM5 system collects 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.

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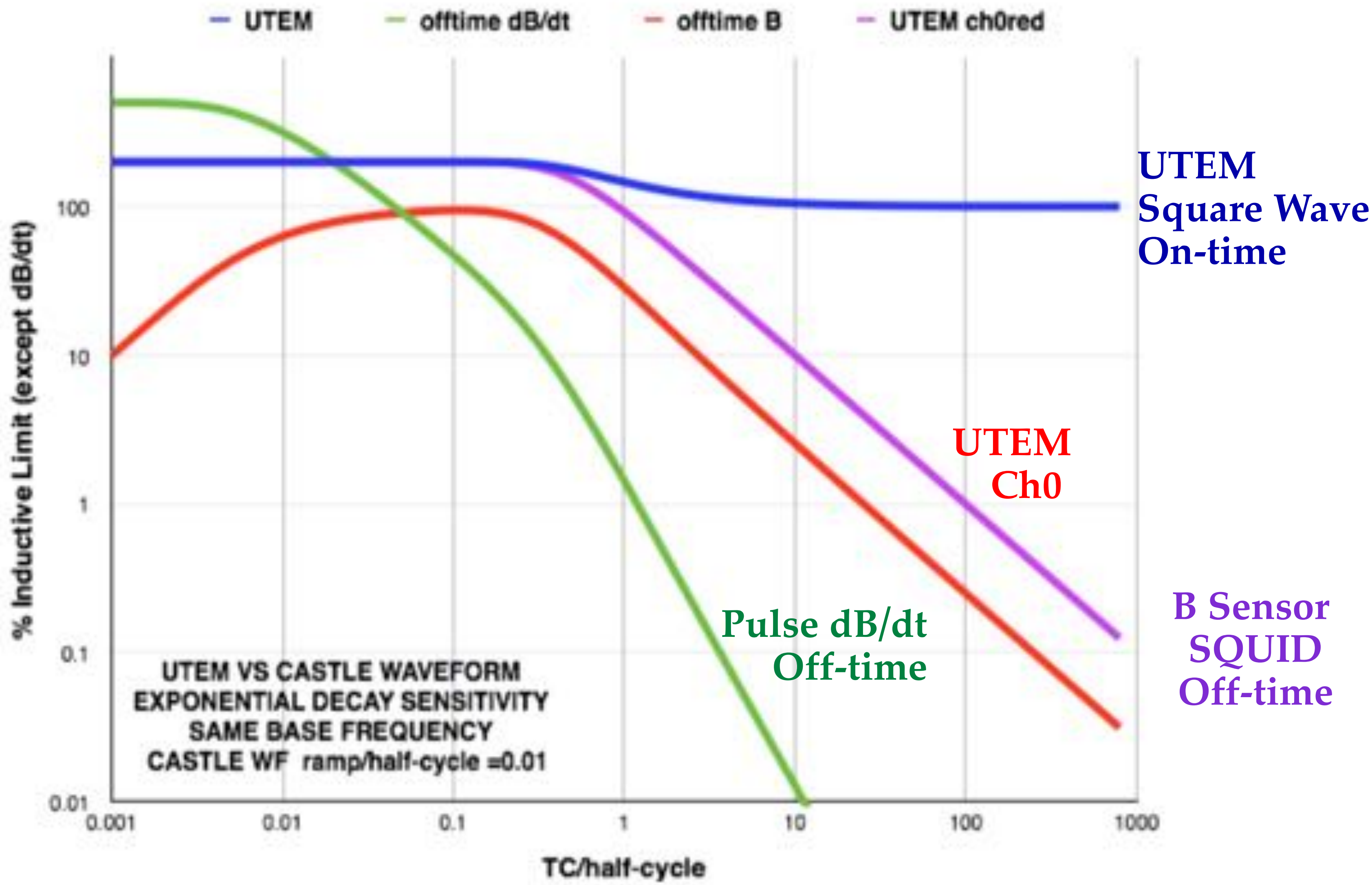
Sensitivity of Waveform/Sampling For Exponential Decays



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Quo Vadis?

VHMS deposits are high value deposits for base metals and become more enticing with the addition of precious metals such as gold. Historically, the search for base metals has been looking for conductors using the EM technique in direct detection.

Greenstone belts are considered favourable geology. The Abitibi and Flin Flon belts are well endowed with gold and base metal deposits with new mines and extensions to existing mines continually being found even though each belt have been considered to be well explored. Numerous airborne EM systems have been flown over these belts with no major discovery occurring in the last 20 years. Forty thousand anomalies were generated in the Abitibi from Megatem where they were screened on strict geological criteria and not on their conductive criteria because they could not be rated using the EM.

In the Flin Flon belt, Spectrem was flown, again with thousands of anomalies being selected. However, It is worth noting that the Spectrem system is the closest airborne system to UTEM, with a late time component. Ten late time anomalies were selected and 2 became mines (Photo and Konuto) with a further 20 targets yielding significant intersections under limestone cover. Since 2007 complete VTEM coverage was then flown finding the Reed Lake mine and Lost deposit for Halo. All the targets detected are shallow. ZTEM blocks have been flown over the high interest areas including Lalor Mine which is anomalous.

The paper Quo Vadis Exploration? states a 'gap' exists for finding blind deposits below overburden from 50m down to 200m depth. Why? The conductive anomalies all appear similar. Some 3D modelling helps to explain this.

As ever, the dream is for new large base metal deposits (> 10m tonnes) to be found. Only one major new mine, Lalor, has been found. Pulse BHEM is accredited for this discovery.

The UTEM5 system is an on-time broadband system measuring the step response of the ground.

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Case Studies

VHMS discoveries attributed to using the UTEM system include:

Hellyer in Tasmania, Australia - Aberfoyle-Cominco-Teck
Neves Corvo – Lombador Deposit? in Portugal - Lundin Mining
Heninga in NWT - St. Joe Minerals
Kudz Ze Kayah in Yukon - Cominco-Teck

UTEM test surveys proving technology:

Que River in Tasmania, Australia - Aberfoyle-Cominco-Teck
Lalor Deposit in Manitoba – Hudbay Minerals
Izok Lake in NWT – MMG
Selbaie* (Brouillan) in Quebec – BHP
* After discussion with L. Reed classified as hydrothermal and is not a VMS

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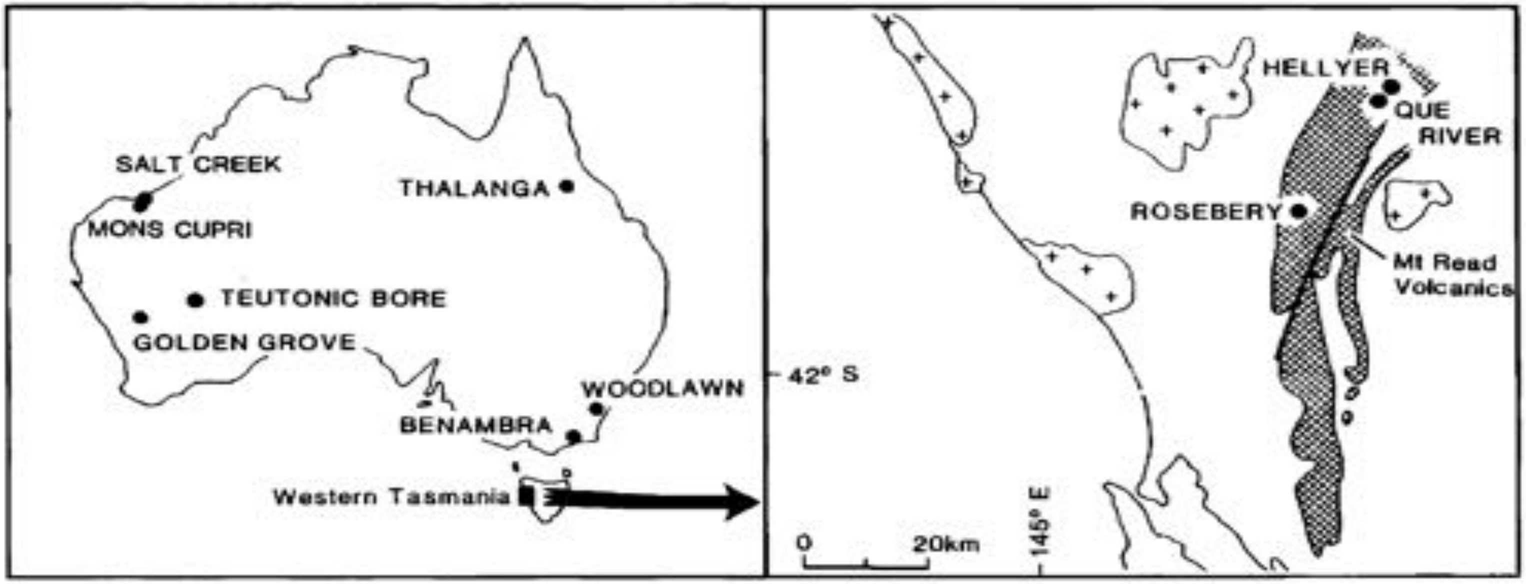
Que River, Tasmania Case Study



Que River* in Tasmania, Australia - Aberfoyle- Cominco- Teck

The 'S' lens is low grade and uneconomic. The 'S' lens was discovered from an airborne EM anomaly. The 'PQ' lens was fortuitously found by drilling. A UTEM test survey was then carried out over the Que River deposit for deep penetration and also used to compare to other geophysical systems including Sirotem. Only UTEM was able to locate the PQ lens as a late time anomaly because it was more conductive than the 'S' lens. (see next slide) Aberfoyle geophysicists then had the confidence to use UTEM routinely for exploration on the west coast of Tasmania.

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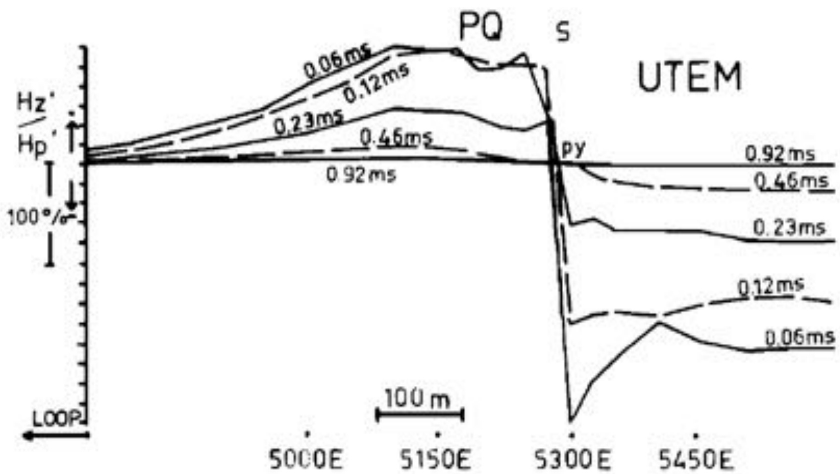
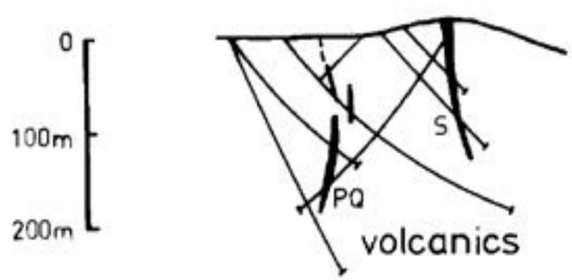
Que River, Tasmania Case Study





Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Que River	PQ lens S lens	20S 9S	150m	600m	9m	100m	85°

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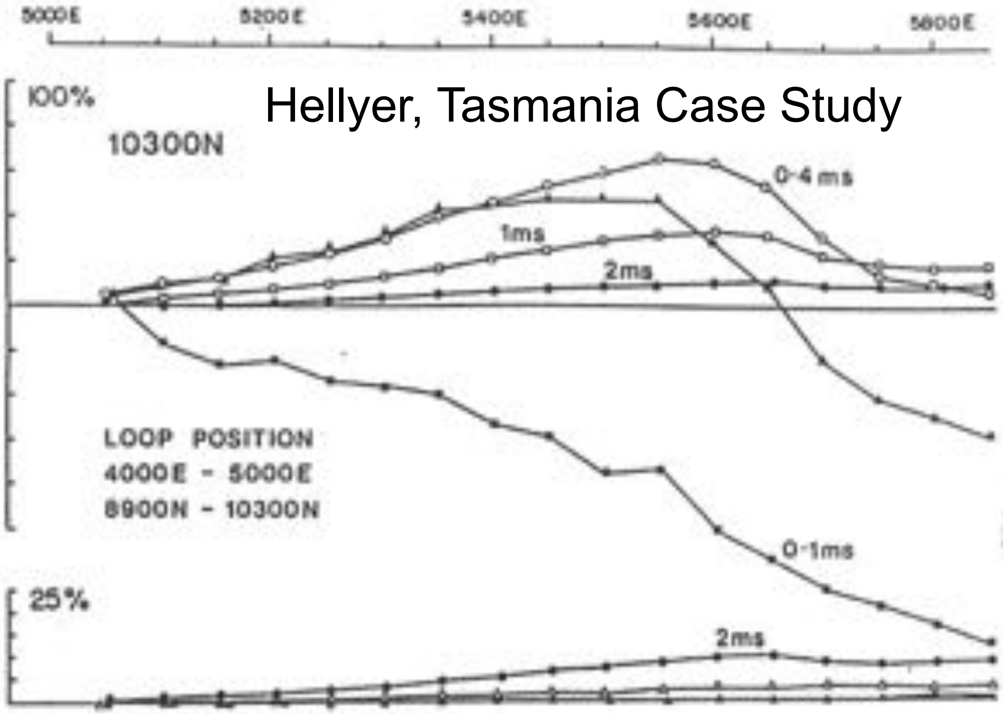
Hellyer, Tasmania Case Study



Hellyer in Tasmania, Australia - Aberfoyle - Cominco – Teck

The northern two thirds of an andesitic unit was surveyed. The grid area was extended far enough north to determine the UTEM response of some disseminated sulphides encountered when drilling an IP/Geochem anomaly in 1982. The most northern line was placed at 10300N where a UTEM anomaly was detected (this slide) as a late time response like Que River PQ response. The survey was extended another 400m to the northern extent of the outcropping volcanics. Detailed UTEM define a deep, moderately conductive body. Surface mapping revealed a pod of Barite and intense alteration concentrated in the nose of an anticline overlying the conductor, which was in an area known to have anomalous Pb and Zn in soils. The combination of these factors made the target a high priority drill target.The first hole intersected 24M of base metal mineralization and the Hellyer ore body was discovered yielding 17 million tonnes of Pb/Zn ore.

Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Hellyer		50S	750m	200m	30m	100m	0

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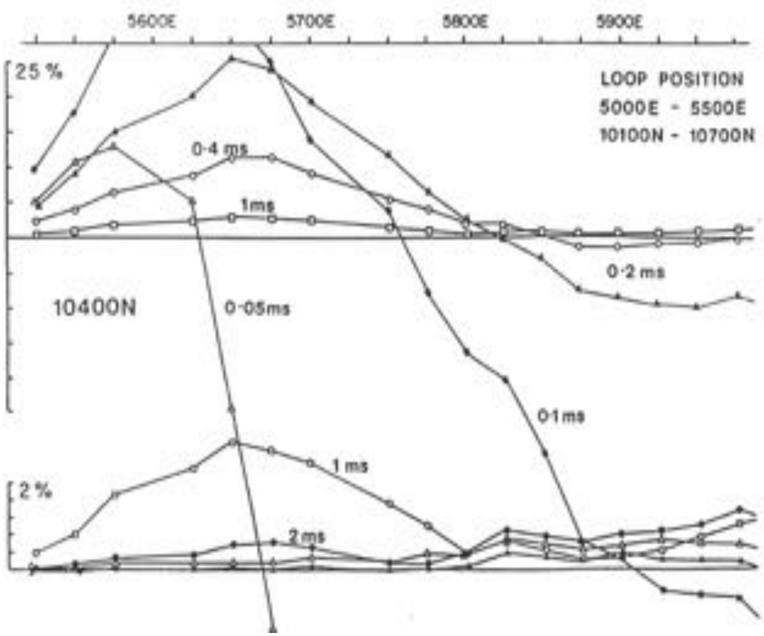
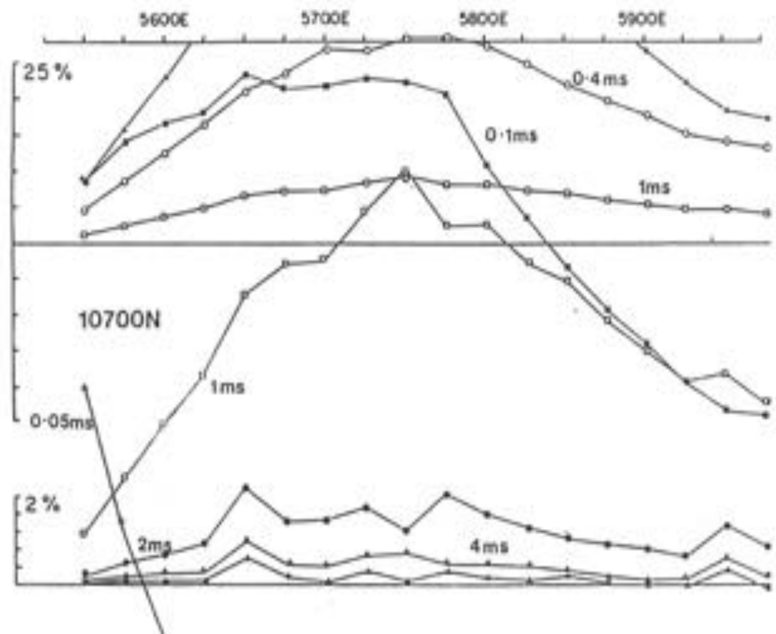
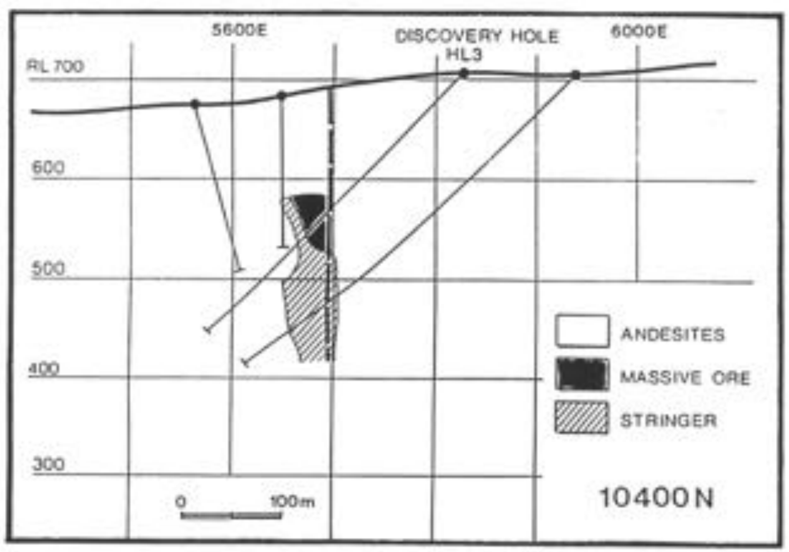
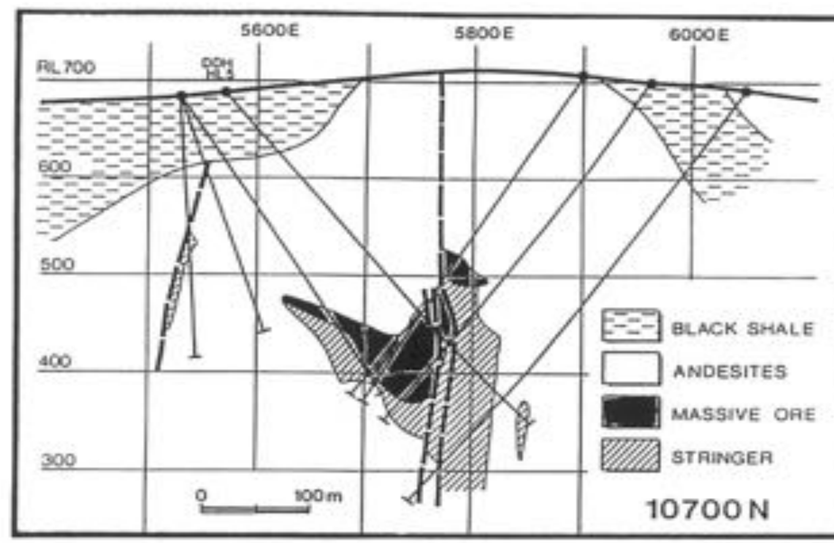




Hellyer, Tasmania Case Study





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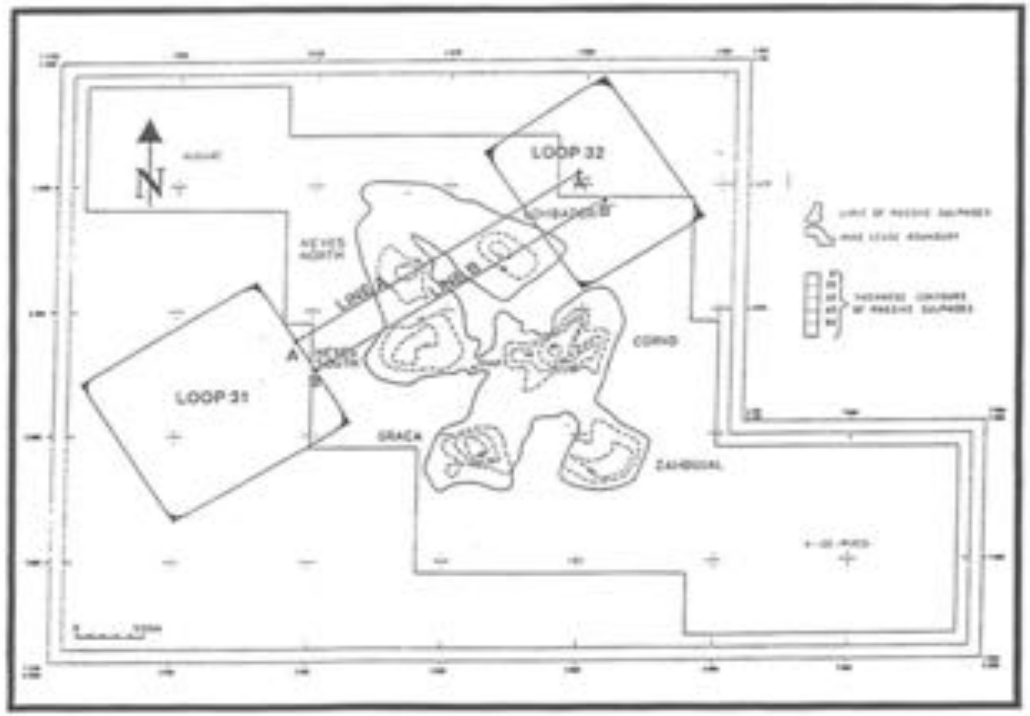
Neves Corvo, Portugal Case Study

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.

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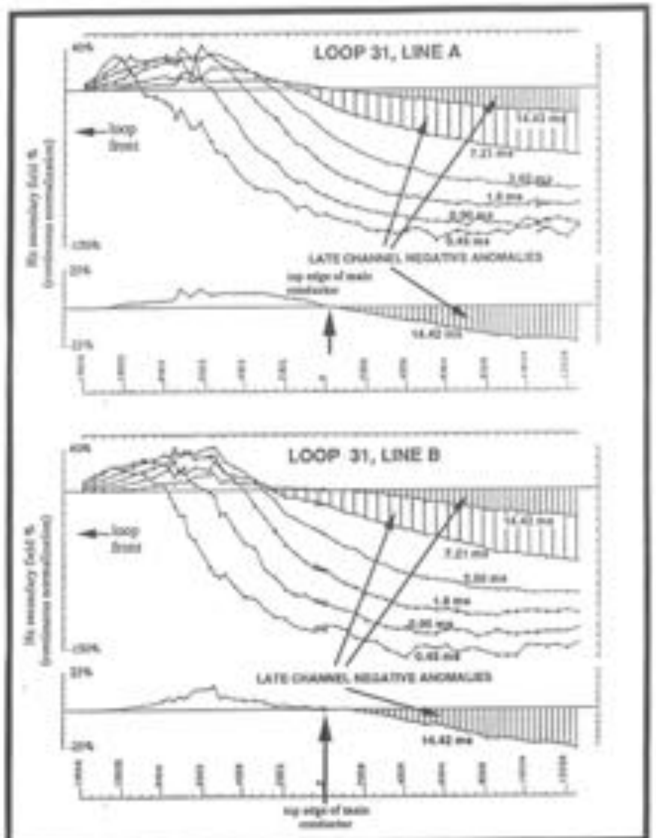
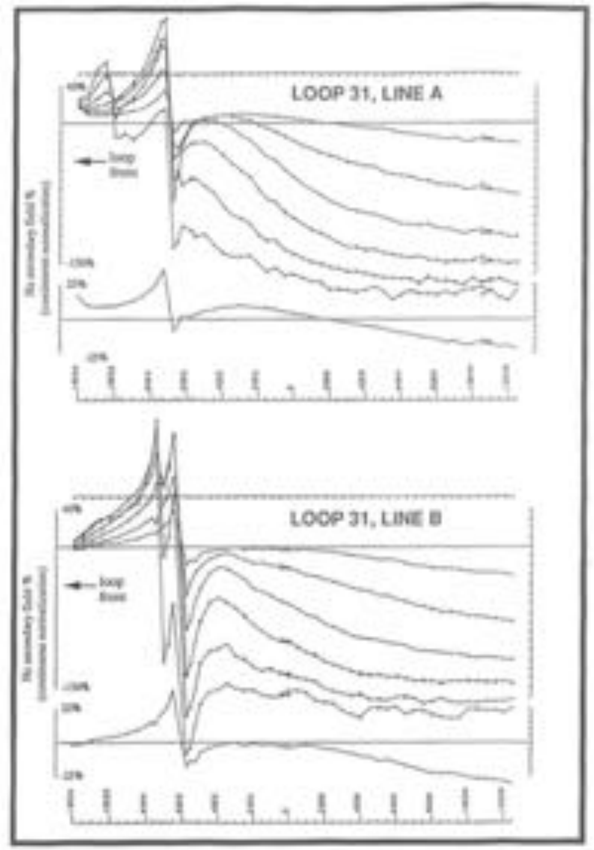
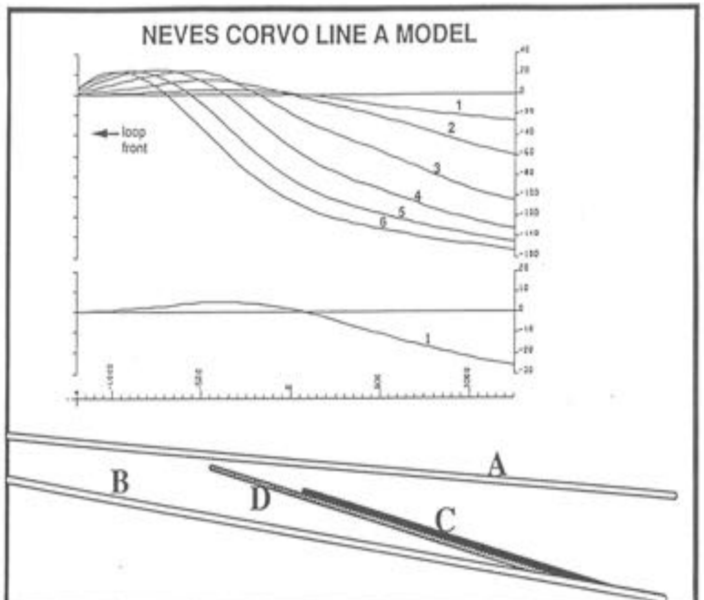
Neves Corvo, Portugal Case Study





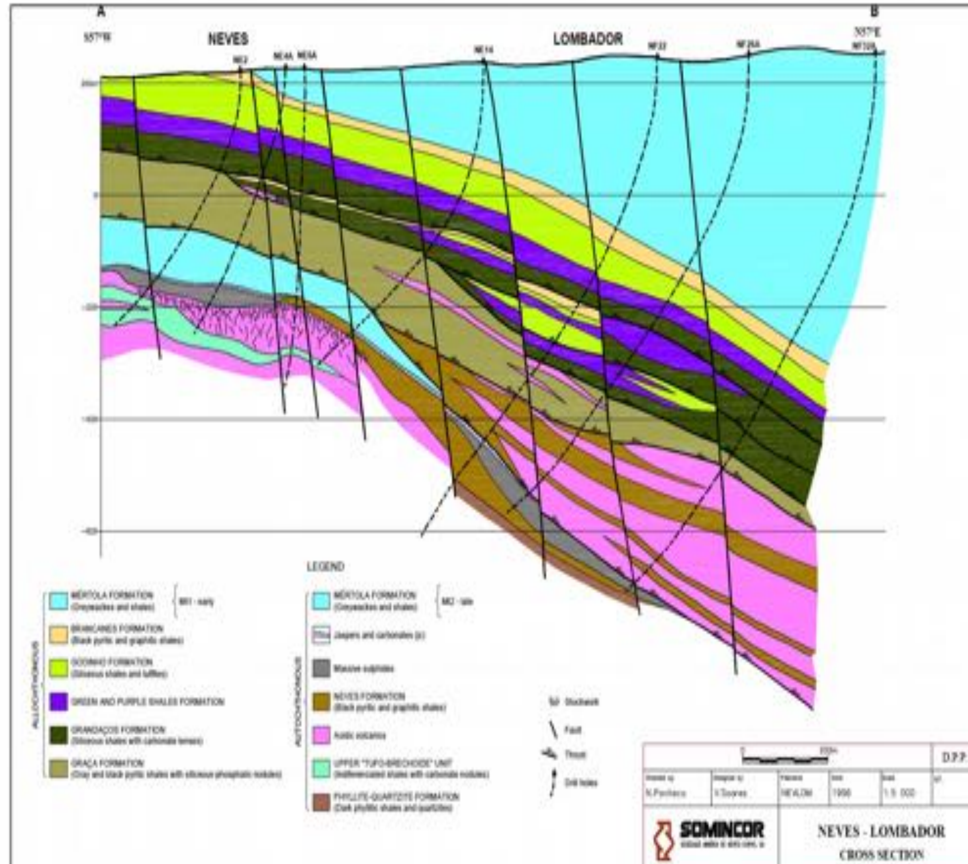
Right Image shows large amplitude cultural anomalies due to power lines which needed to be stripped from the data. Left image shows interpreted data clearly identifying the Lombador zone prior to drilling.

Neves Corvo, Portugal Case Study



Conductor Parameters

A:	conductive cover layer dip = 5 degrees conductance = 1.5 siemens strike extent = 8000m dip extent = 8000m	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 = 8000m dip extent = 8000m	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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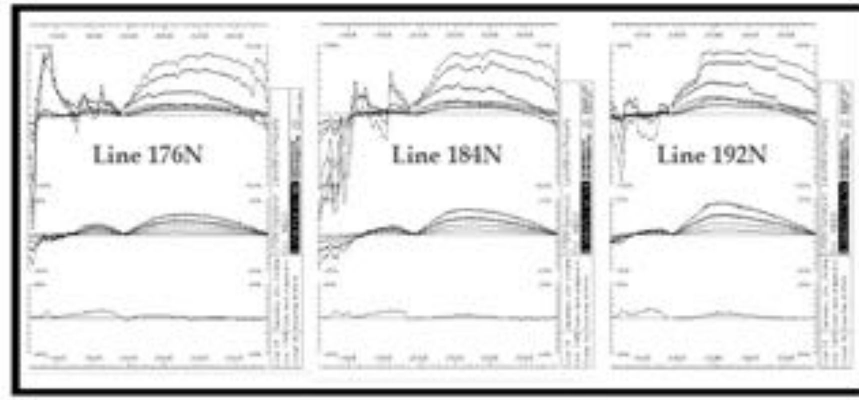
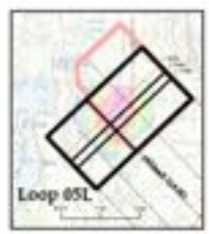
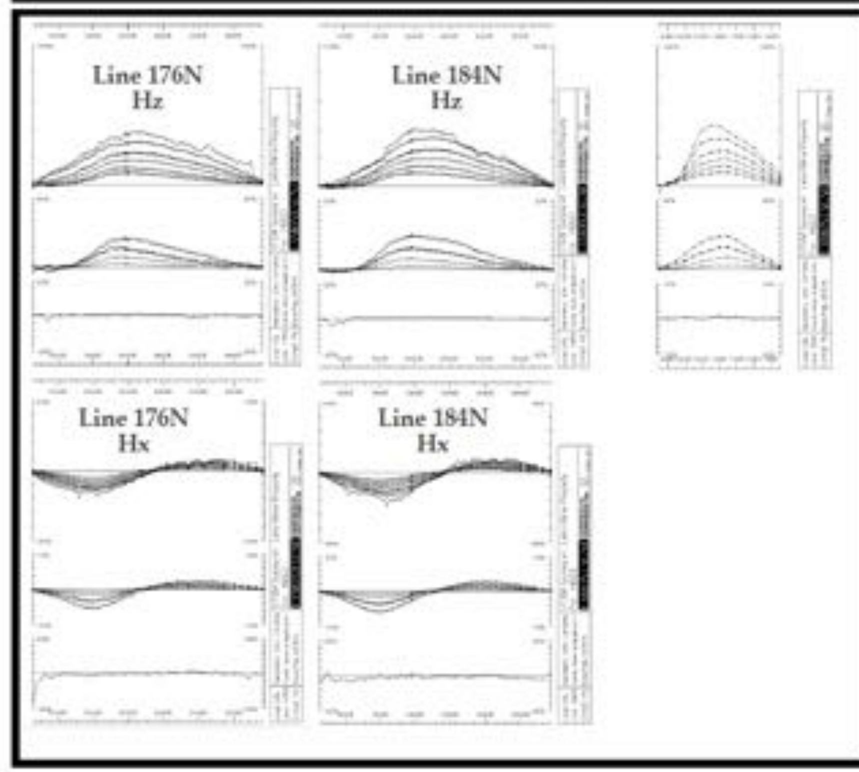
Lalor, Manitoba Case Study

Loop 05
30Hz



Loop 05L
4Hz





Lalor Deposit in Manitoba – Hudbay Minerals

Lines 192/184/ 176N were opened up to industry as test survey lines for the detection of the Lalor deposit UTEM 3 was completed at 30Hz (this slide, top right using Loop 5 - the deposit is clearly detectable. A secondTx Loop - 5L – was designed to couple with th entire deposit. Lines 184/176N and cross Line 63E were then read at 4Hz. Two components, Hz and Hx, were measured using UTEM 3 (bottom right).

MultiLoop modelling results over the published mineralization (from 43-101) are shown for: a single sheet of 300S modelling the Upper/Lower Chisel contact surface. The footwall/mineralization package and associated alteration is modelled with a broader 50S plate. Zn-rich base metal zones 10,11,20,30,31,40 are roughed in as 300S plates erring on the larger size (next slide, top). Note: conductances are ~minimums as the response is visible on the latest Ch (0.117s).

A UTEM5 survey repeated this work and then Line 184N was then reread at 0.25Hz (next slide, mid). Th Lalor response is visible on the latest time Ch (2.09s) Subsequent MultiLoop modelling of the UTEM5 data shows a plate with ~10 times the (300S) conductance is needed to explain the response.

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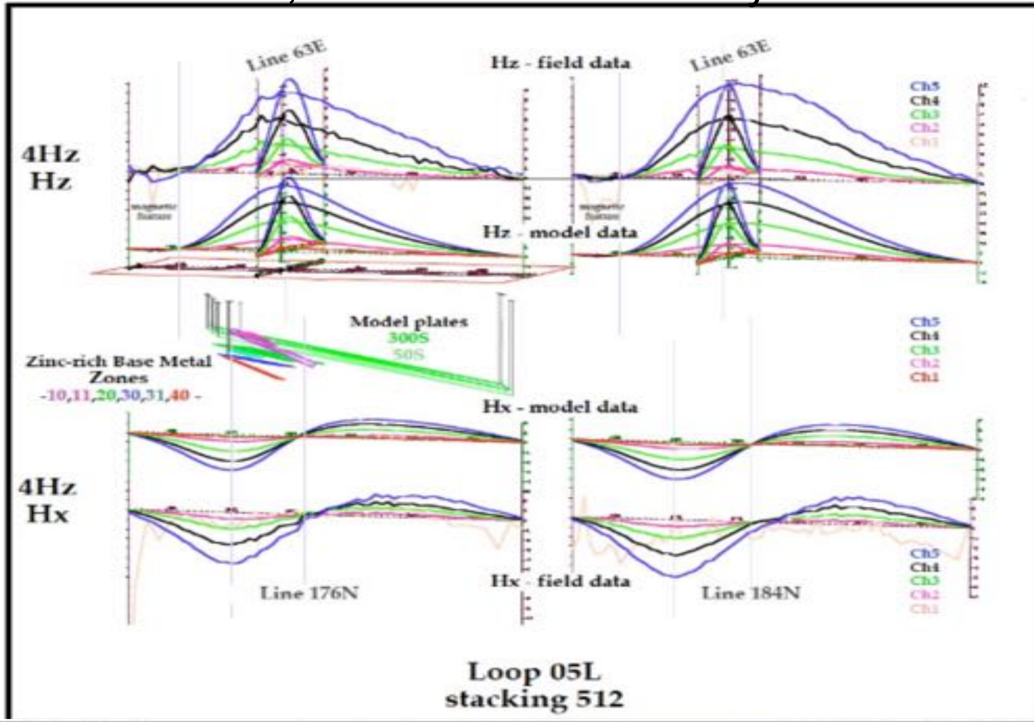
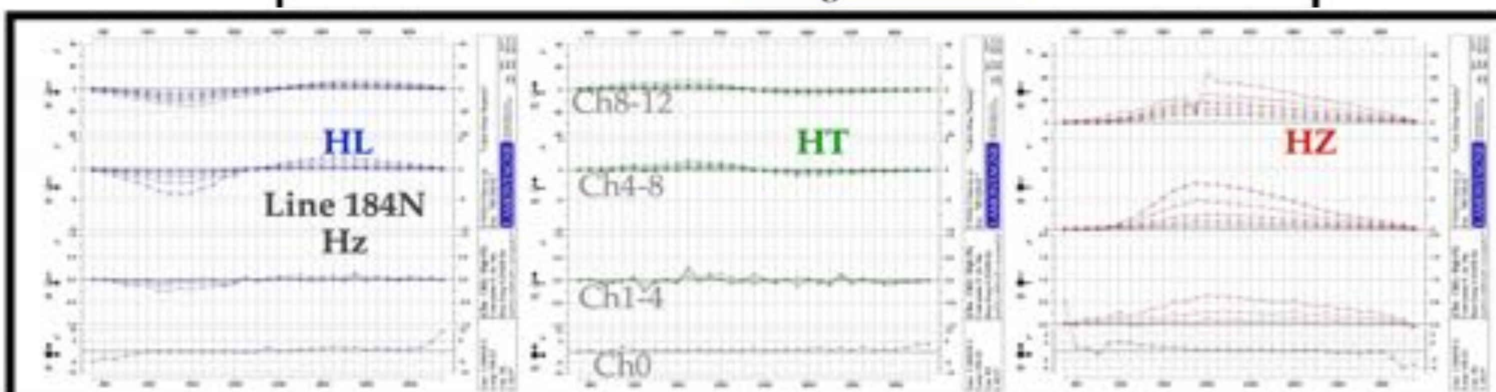
Lalor, Manitoba Case Study

Modelling with MultiLoop



UTEM5
Reading at 0.25Hz
Base frequency



Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Lalor	10,11,20,27,30,31,40 Alteration	300S 50S	900m	600m	15m	570-1170	15-20°

Selbaie (Brouillan), Quebec Case Study

Selbaie (Brouillan) – Selco - BHP

The Selbaie base metal ore deposit is located about 100 km west of Matagami in Quebec. It consists of a variety of disseminated and stringer type sulphide deposit in an Archean meta-volcanic sequence, the Abitibi greenstone belt. There are two main zones of mineralization called A and B zones. The A zone is located 1km east of the B zone. An INPUT air EM survey showed a clear linear anomaly in each zone. Both anomalies having comparatively rapid decay rates. Mineralization is not confined to the main conductive zones and close analysis of the INPUT EM shows that a halo has produced some of the response. Over zone A the overburden is moderately to poorly conductive and is only 3-5m thick. The mineralization mostly subcrops at the bedrock surface. However, the eastern part of zone A, plunges under non-mineralized formations to depths of 50-80m.

The UTEM survey was the first extensive survey undertaken and was carried out over much of the A zone. The survey layout (map, right) consisted of a pair of Tx loops, north/south of the survey area. Measurements were of the vertical magnetic field Hz and of electric field components Ex and Ey with a grounded dipole of 25m length. Base frequency was 17 Hz for the south loop and 34Hz for the north loop.

Strong H field crossover type anomalies are observed on all lines to the west of L3W (see stacked profiles, next slide). The large amplitudes indicate a relatively near-surface source, yet the cross-over is very broad, with several inflections and the cross-over point varies from one Ch to the next. This indicates a broad zone of weak, irregular conductivity, with the most conductive part between 1W and 2W on most lines. East of L6W, the anomaly amplitude on any given channel declines, correlating with the increasing depth-to-top. The more conductive part has a a conductance of 5S and is about 100m wide. The anomaly sits within a broad 'halo' with a resistivity in the order of 100-200 ohm-m.

Note the interpretation is hand drawn. (forward 2 slides). The poor conductor to the south of the main zone is seen only in the Efield data.

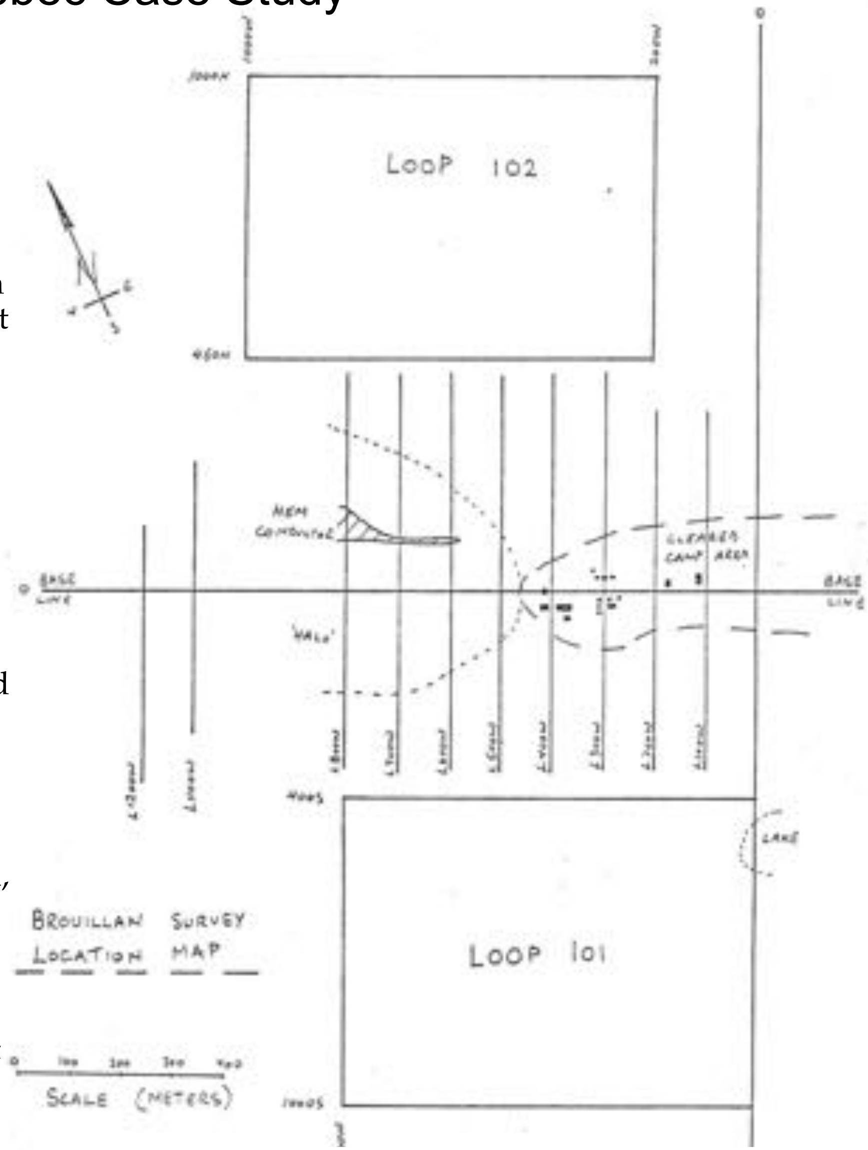


FIG 1

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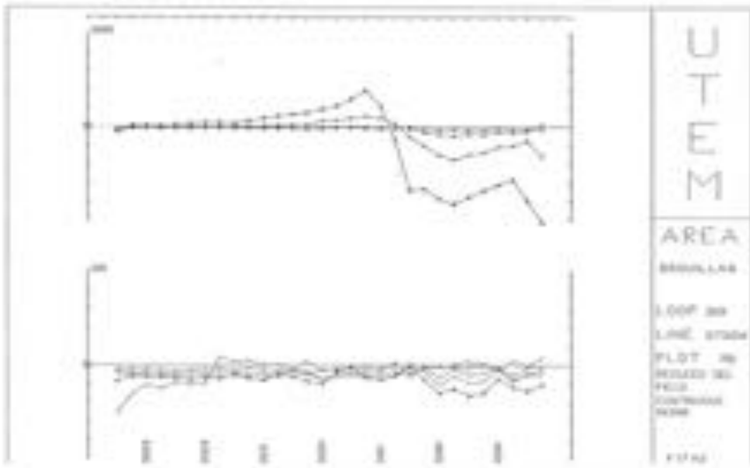
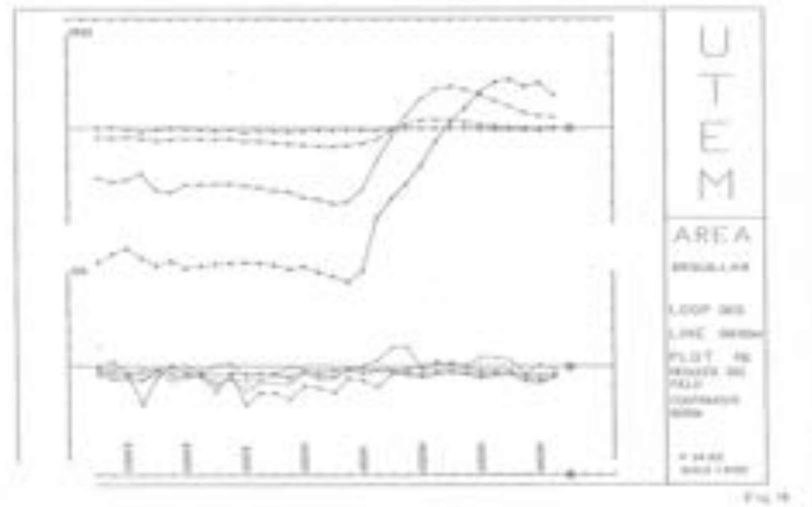
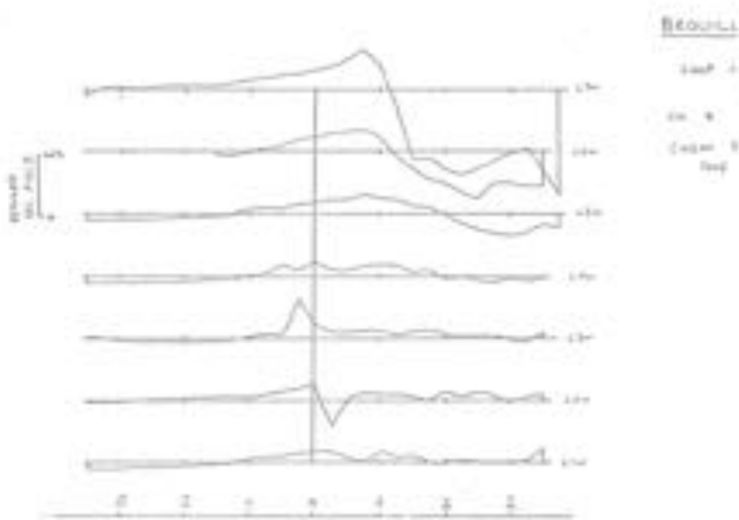
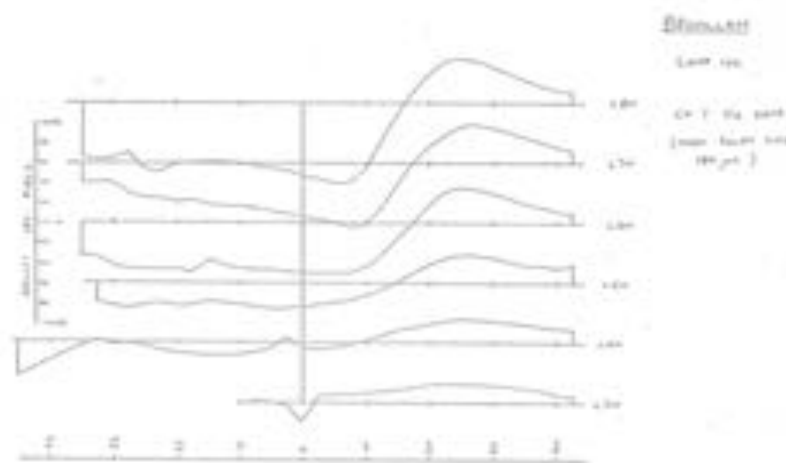
Selbaie (Brouillan), Quebec Case Study









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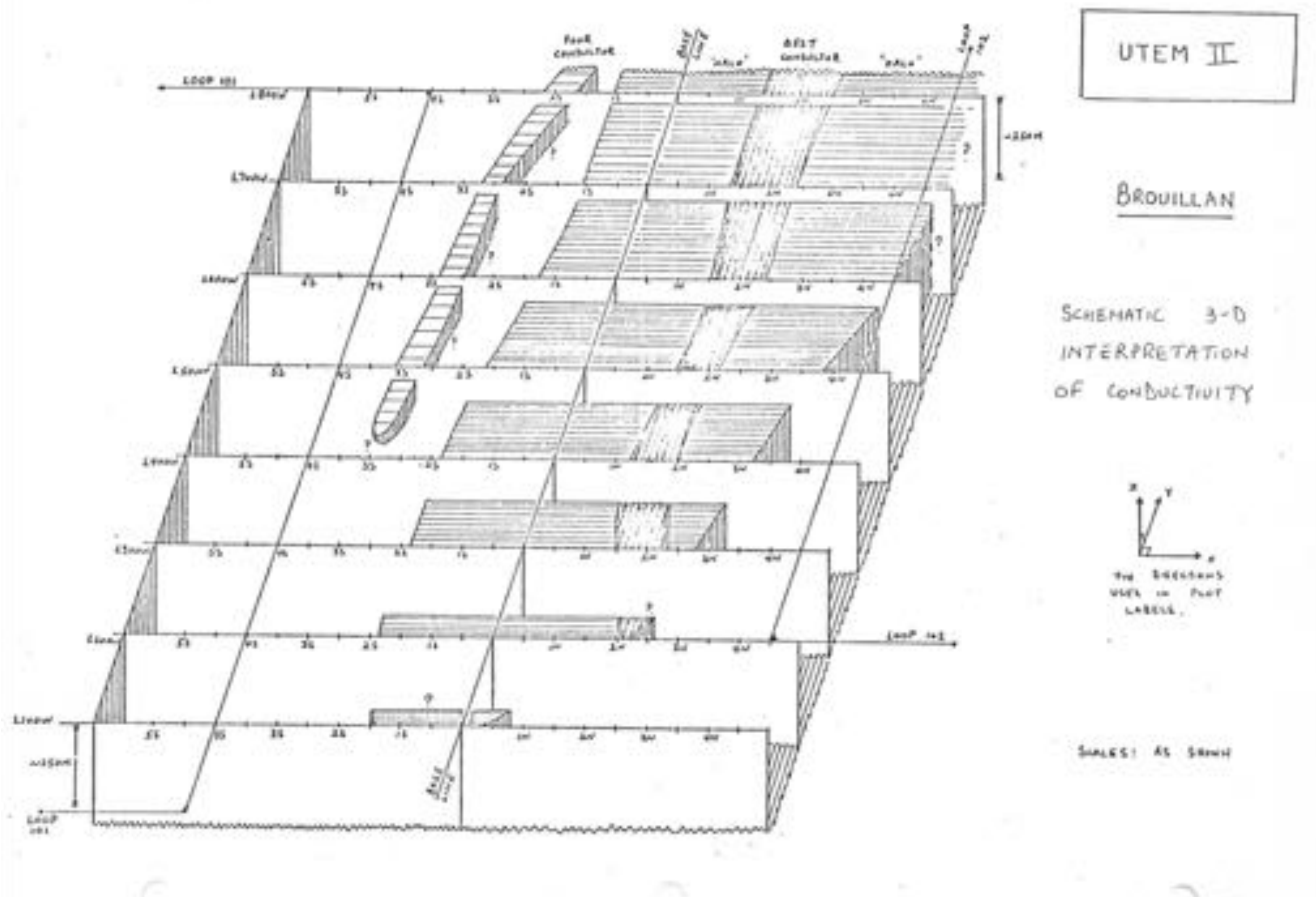
Selbaie (Brouillan), Quebec Case Study



Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Selbaie (Brouillan)	Core	5S	600m	80		~0m	
	Halo		800m	400m		~0m	

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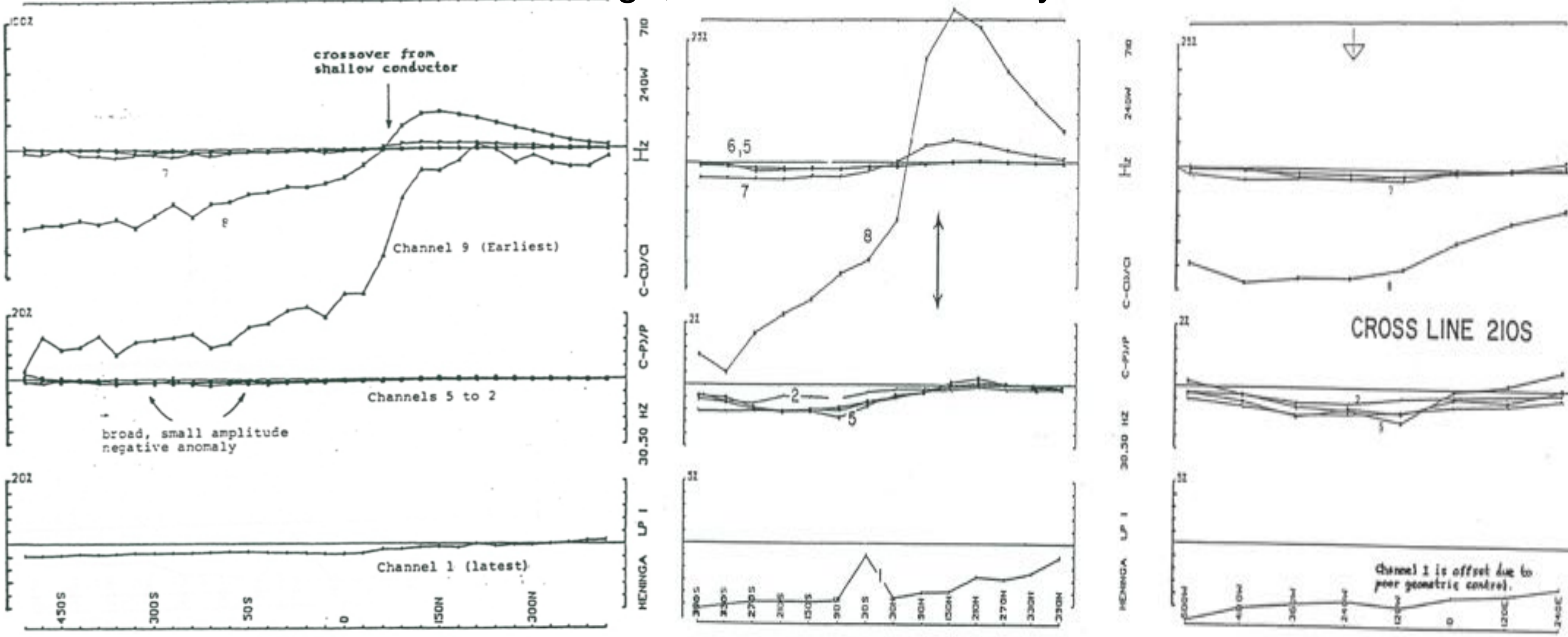
Heninga, Nunavut Case Study

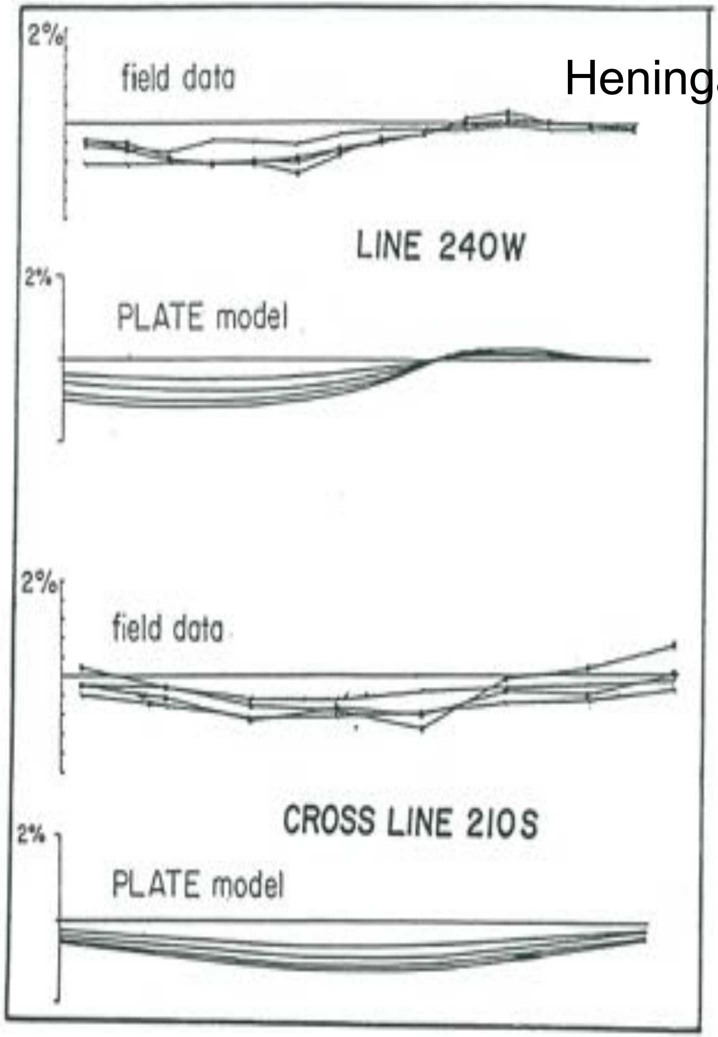


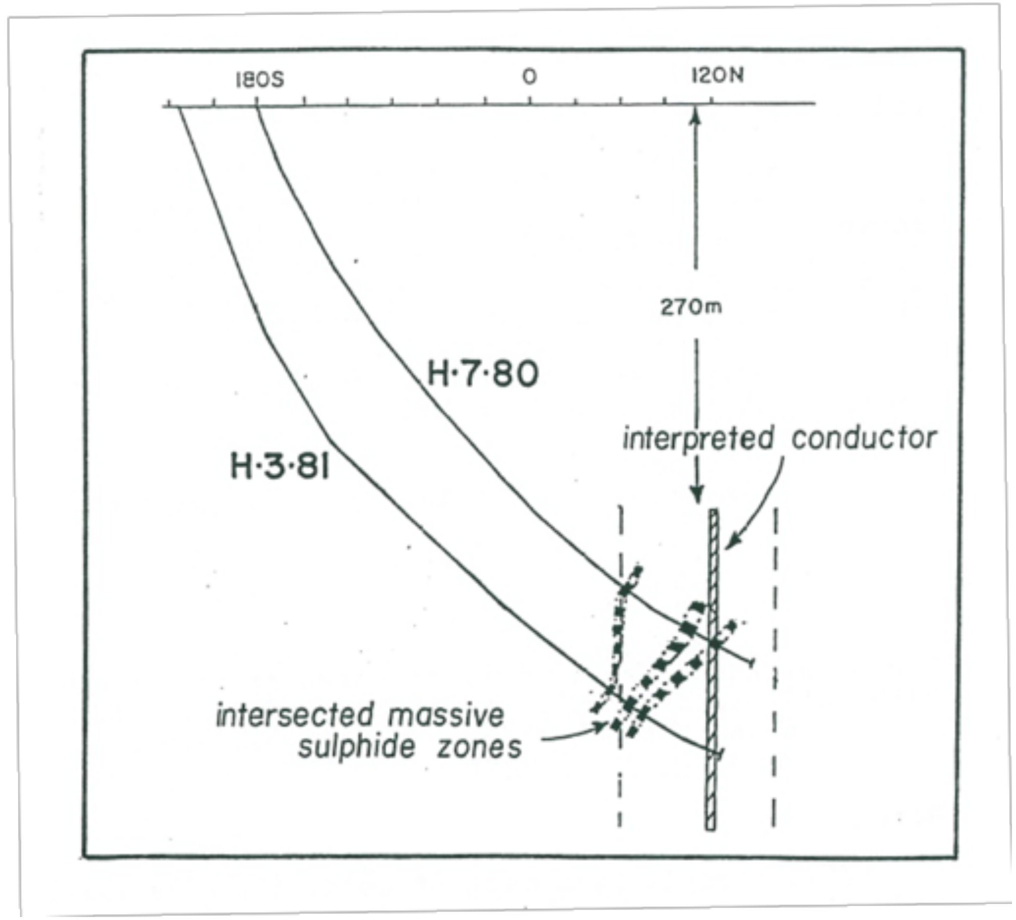
Heninga Lake in Nunavut - St. Joe Minerals – Agnico Eagle JV

Located 400km due north of Churchill, MB in Nunavut. The host rocks are a Pre-Cambrian volcanogenic sequence. The mineralization occurs within layered intermediate to felsic volcanics, mainly finer grained lapilli tuffs, grading upwards into finer grained volcano-clastic sediments and low grade magnetite iron formation. Two new zones were detected by the UTEM survey. The AB-II Deep zone at an interpreted depth 100-150m. It was not previously recognized because of associated overlying poorly conductive material. The UTEM zone was interpreted to be very deep and was located within the main zone (this, next slide).

Most evident at first glance is the cross over centred at 60N on the early time data (Chs 9/8/7). This corresponds to poorly conductive material in the near surface. Chs 5-2 - later times - are plotted on the middle axis at an expanded scale (centre, above). Towards the south end of the profile there is a broad, slowly decaying, negative anomaly of very small amplitude (<2%) noted. Interpretation detected with complete confidence the presence of a finite, very deep conductor. Interpretation of location and geometry was difficult due to the small amplitude. Depth-to-top of the conductor was 270m. Strike and depth extent both about 200m. The conductance of the zone was very high at 500-1000S. Successfully drilled, the main zone at Heninga Lake consists of 6 zones of mineralization with a strike length of 120m. The AB-II zone has 3 zones of mineralization within a strike length of 700m. (see next slide)

Heninga, Nunavut Case Study





Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Heninga Lake	Main Zone AB-II Zone	500S	120 700m	200m	6,5,2m	270m	90°

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Izok Lake in Nunavut – Texas Gulf - MMG

The anomalies caused by the Izok deposits are recognized on the data sections 12-30E. Mostly negative anomalies or 'top anomalies' with positive side lobes as would be produced by nearly horizontal finite plates. The extent of the negative anomalies (map to right, next slide) provide a clear picture of the Izok deposits. The anomaly on Lines 12/18/24E near/north of the BaseLine ~delimits the NW Zone; a somewhat narrower response south of the BaseLine on Lines 24/30E is caused by the Central Zone; the narrow sharp negative at 2S on Line 30E indicates the north zone. A single point negative anomaly at 12S on L18E indicates the South Zone. UTEM measurements unambiguously locate the 4 zones of mineralization.

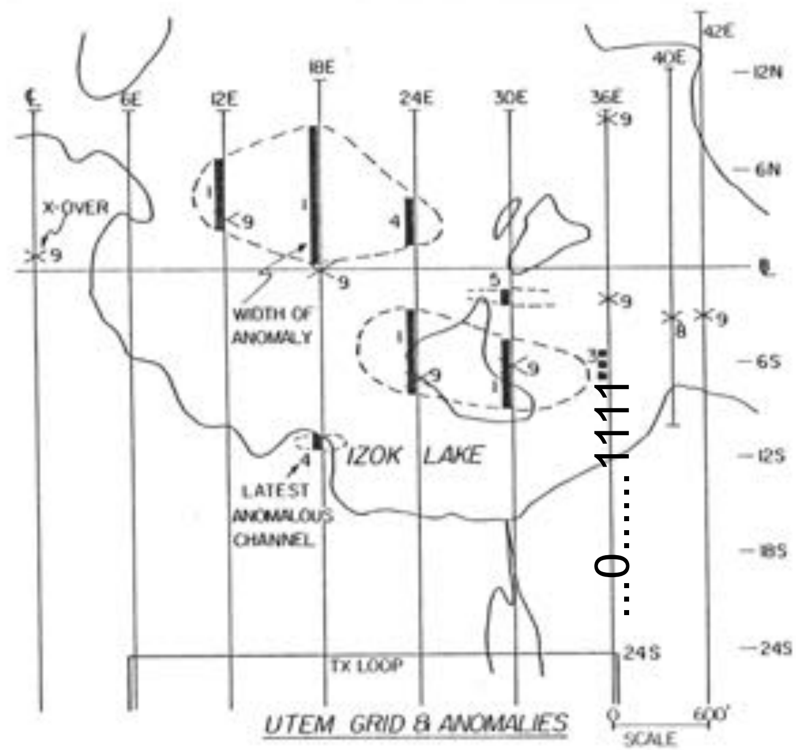
The UTEM data show the value of wide band time domain measurements in discriminating multiple conductors of complex shapes and in assessing their high conductivity in a one pass survey. The advantage of fixed Tx Hfield measurements is the ability to separate multiple conductors of moderate depth extent without compromising the detection of deep targets.

Izok decay curves and values are noted in the next slide. Of major interest is how the the time channels are equally spaced. The calculated conductances are conductivity-thickness products which best fit the late portion of the decay. The positive discrepancy between the modelled/measured decays can be attributed to thickness effect and/or the presence of a conductive halo. Assuming it to be thickness effect, the time of disappearance gives an estimate of model thickness - meaningful if the conductivity is uniform.

The Central zone conductance is double (or more) that of the NW Zone. The east part (~L30E) of the Central Zone is much more conductive than the West Zone on L24E. The NW Zone west part (~ L12E) seems the most conductive, but deeper and narrower. The much narrower North Zone is considerably less conductive.

The correlation between the interpreted conductances and the abundance and thickness of sulphides is qualitatively excellent. The geological sections show evidence of non uniformity in sulphide content. Most evident is L24E of the Central zone where zoning is well developed (higher thickness effect) compared to L30E no zoning. The anomaly enhancement on L24E maybe greater conductor thickness and also by the 'halo' of less conductive sulphides above the copper rich bottom core.

Izok Lake, NWT. Case Study



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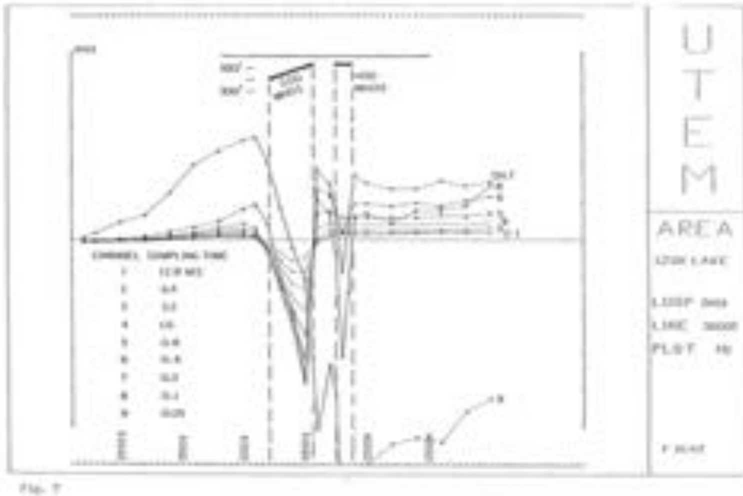
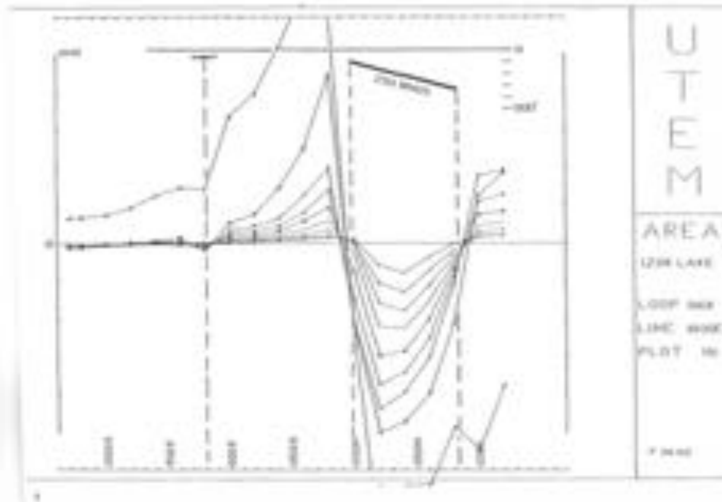
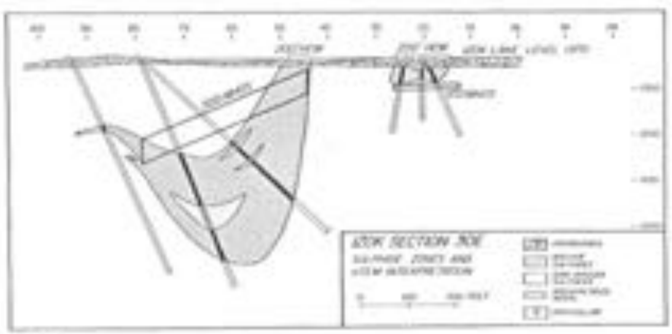
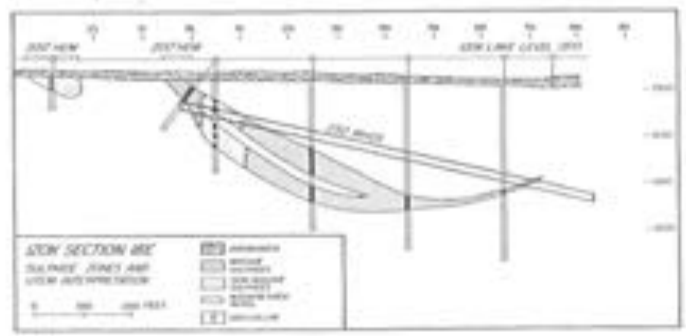




Izok Lake, NWT. Case Study





Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Izok Lake	Main zone	350/500S	200m	130	90m	~0m	10-20°
	NW Zone	250S	500m	230	40m	~0m	0-10°
	North Zone	100S	100m	100m	20m	~0m	0°

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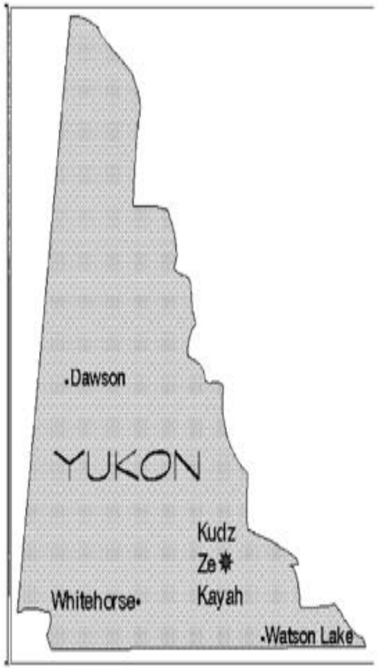
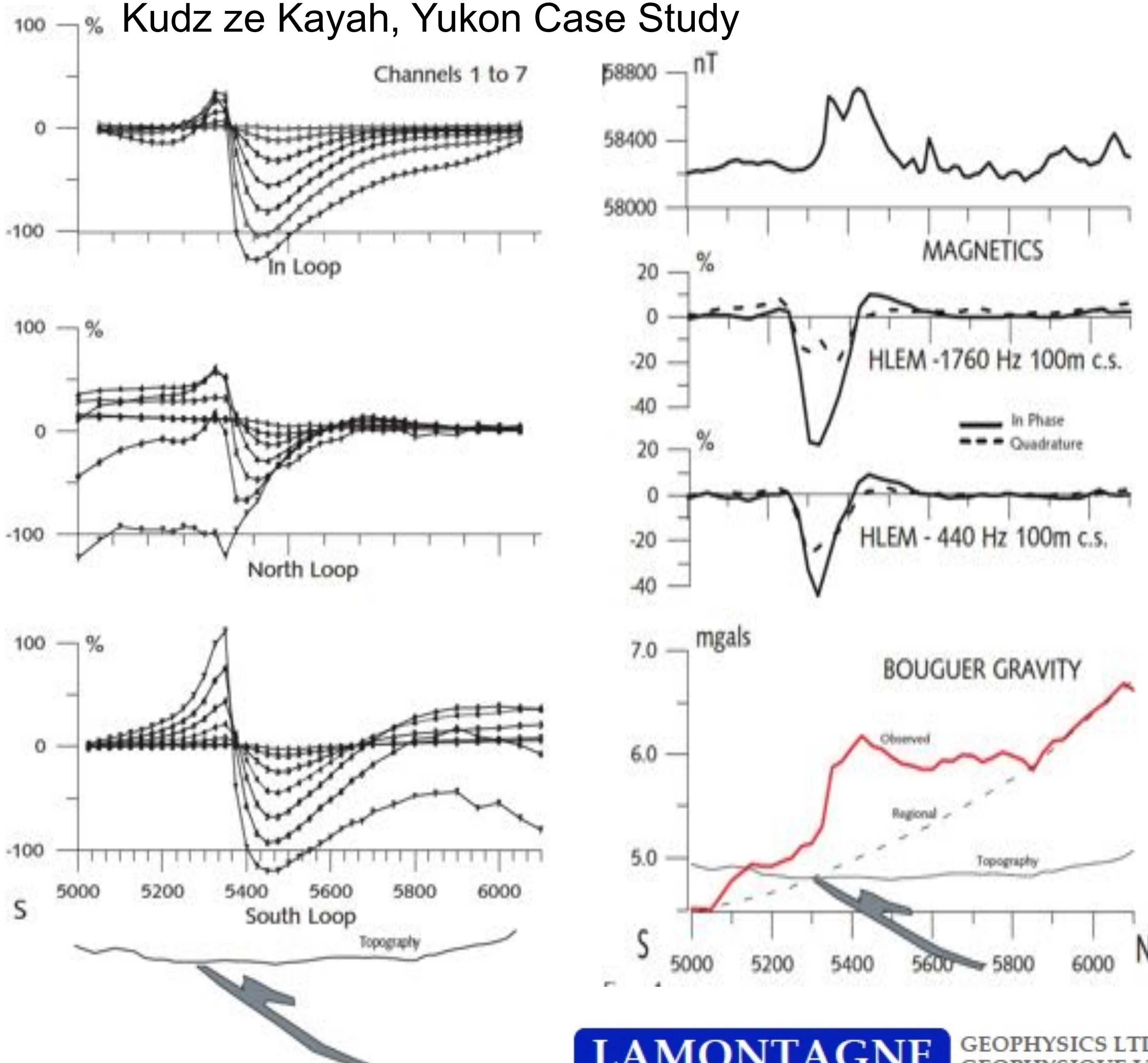
Kudz ze Kayah, Yukon Case Study





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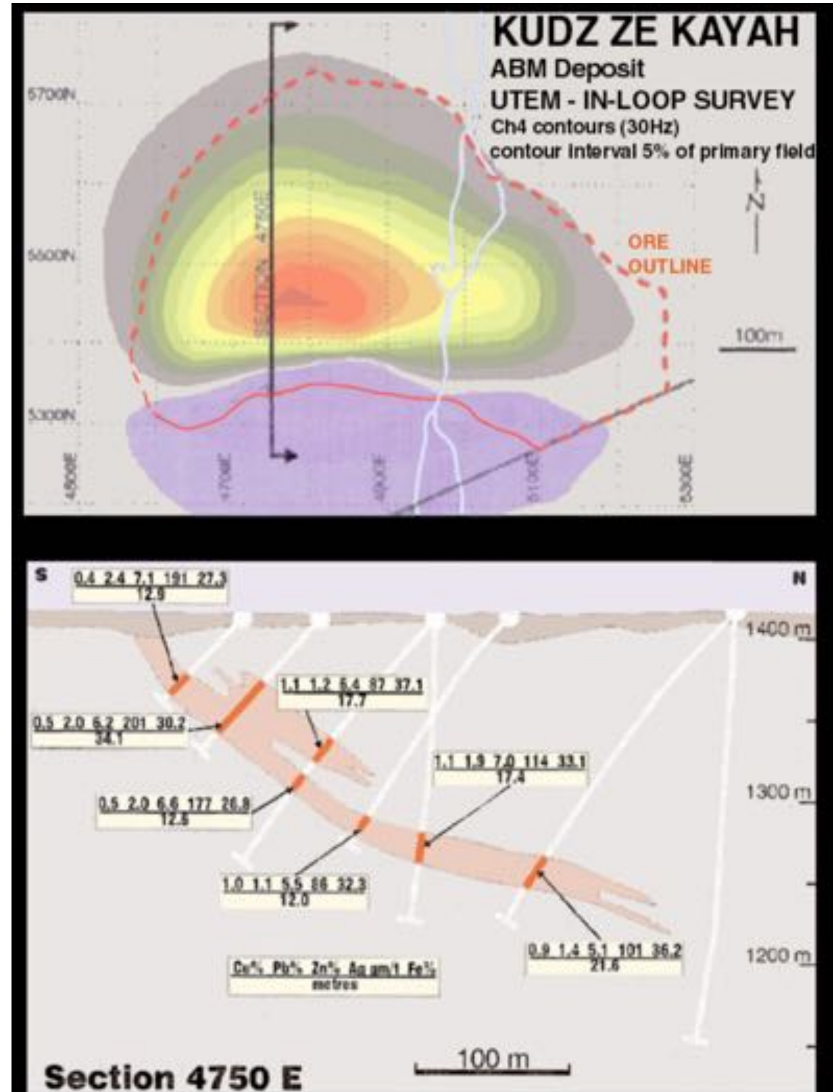
Kudz Ze Kayah, Yukon Case Study

Kudz Ze Kayah in Yukon - Cominco – Teck

A one day reconnaissance UTEM survey carried out with the Tx loop located 1km south of outcropping sulphide boulders. The survey indicated a conductor was located under the loop, outside of the area surveyed. Subsequent reconnaissance mode surveys allowed for the spotting of initial holes. Success was immediate.

The previous slide shows the profile data. The contouring of channel 4 data (this slide, top right) showed a strong correlation with the actual size determined from drilling. Initial modelling interpreted from the first hole intersection provided a tonnage within 5% of the actual tonnage. (pers.comm.)



Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip
Kudz Ze Kaya	ABM	40S	600m	400m	34m	~0m	30°

VHMS Case Study using UTEM - Summary Table

Deposit	Zone	Conductance Siemens	Strike Length	Width	Maximum Thickness	Depth to-top	Dip	Mag Susc *10-6 cgs
Hellyer		50S	750m	200m	30m	100m	0	30
Que River	PQ lens	20S	150m	600m	9m	100m	85°	
	S lens	9S						
Neves Corvo	Neves North	65S	1200m	700m	55m	300-400m	0-35°	
	Neves South							
	Graca		700m	500m	80m	230-400m		
	Zambujal		1600m	1400m	15m	400m		
	Corvo		600m		95m	230-800m	40° (NE)	
	Lombador	125S	1600m	1400m	15m	600-800m	35° (NE)	
Lalor	10,11,20,27,30,31,40	300S	900m	600m	15m	570-1170	15-20°	
	Alteration	50S						
Selbaie (Brouillan)	Core	5S	600m	80		~0m		
	Halo		800m	400m		~0m		
Heninga Lake	Main Zone	500S	120	200m	6,5,2m	270m	90°	
	AB-II Zone		700m					
Izok Lake	Main zone	350/500S	200m	130	90m	~0m	10-20°	
	NW Zone	250S	500m	230	40m	~0m	0-10°	
	North Zone	100S	100m	100m	20m	~0m	0°	
Kudz Ze Kaya	ABM	40S	600m	400m	34m	~0m	30°	700-1000

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VHMS Case Study using UTEM - Summary Table (cont.)

Deposit	Resource MT	Grade Cu%, Zn%, Pb%, Ag gm/t, Au	Description	Location	System
Hellyer	17	0.4,14, 7,160, 0	Massive Sulfides	Tasmania, Australia	UTEM3
Que River	3.1 2	0.6, 13.5, 7.5, 200, 3.4 Uneconomic discovery	Massive Sulfides Low Grade Massive Sulphide	Tasmania, Australia	UTEM3
Neves Corvo	31 33 73 3	Cupriferous Ore 8, 1.4, 0.19 Complex Ore 0.46, 5.72, 0, 40, 0 Pyritic Ore <2% Cu, <4% Zn+Pb Tin Ore 2.37% Sn/13.39% Cu/1.3% Zn		Portugal	UTEM3
Lalor	30	12.3mT 0.66, 8.7, 0, 24.2, 1.6, 5.0mT 0.7, 9.3, 0, 5.5, 1.4.	Massive Sulfides FW mineralization/alteration	Manitoba, Canada	UTEM3 then UTEM5
Selbaie (Brouillan)	53	1, 1.9, 0, 41, 0.6		Quebec, Canada	UTEM2
Heninga Lake	6	1.3, 9, 0, 62 , 0.9.		NWT, Canada	
Izok Lake	14.6	2.3, 13.1, 1, 73, 0.2	Zn-Cu Massive Sulphide	NWT, Canada	UTEM2
Kudz Ze Kaya	11.3	0.98, 6.2, 2, 200, 1.34.	Kuroko Py Massive Sulphide	Yukon, Canada	UTEM4

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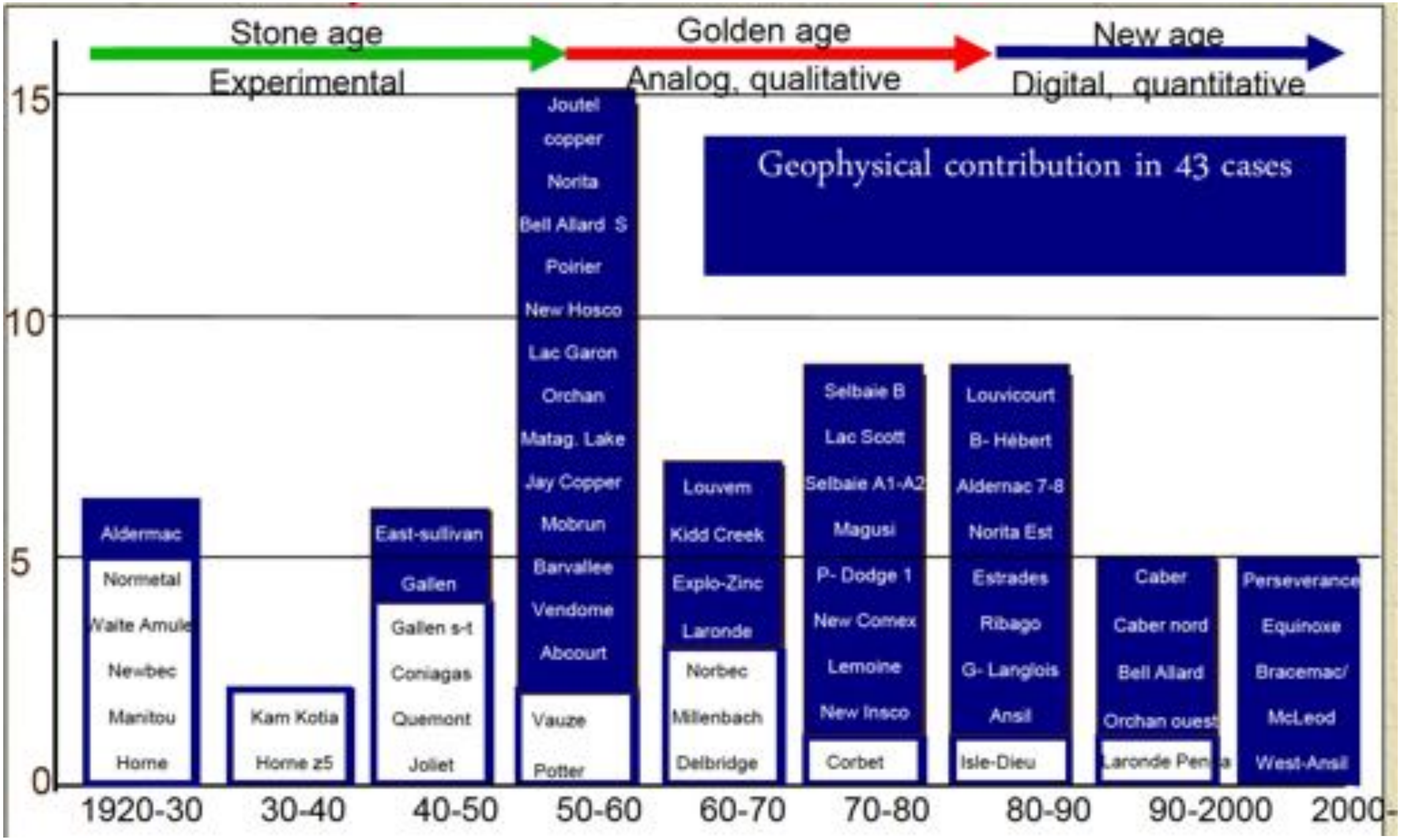
Discovery Versus Time
Lack of New Discoveries



From Allard and Witherley, 2010

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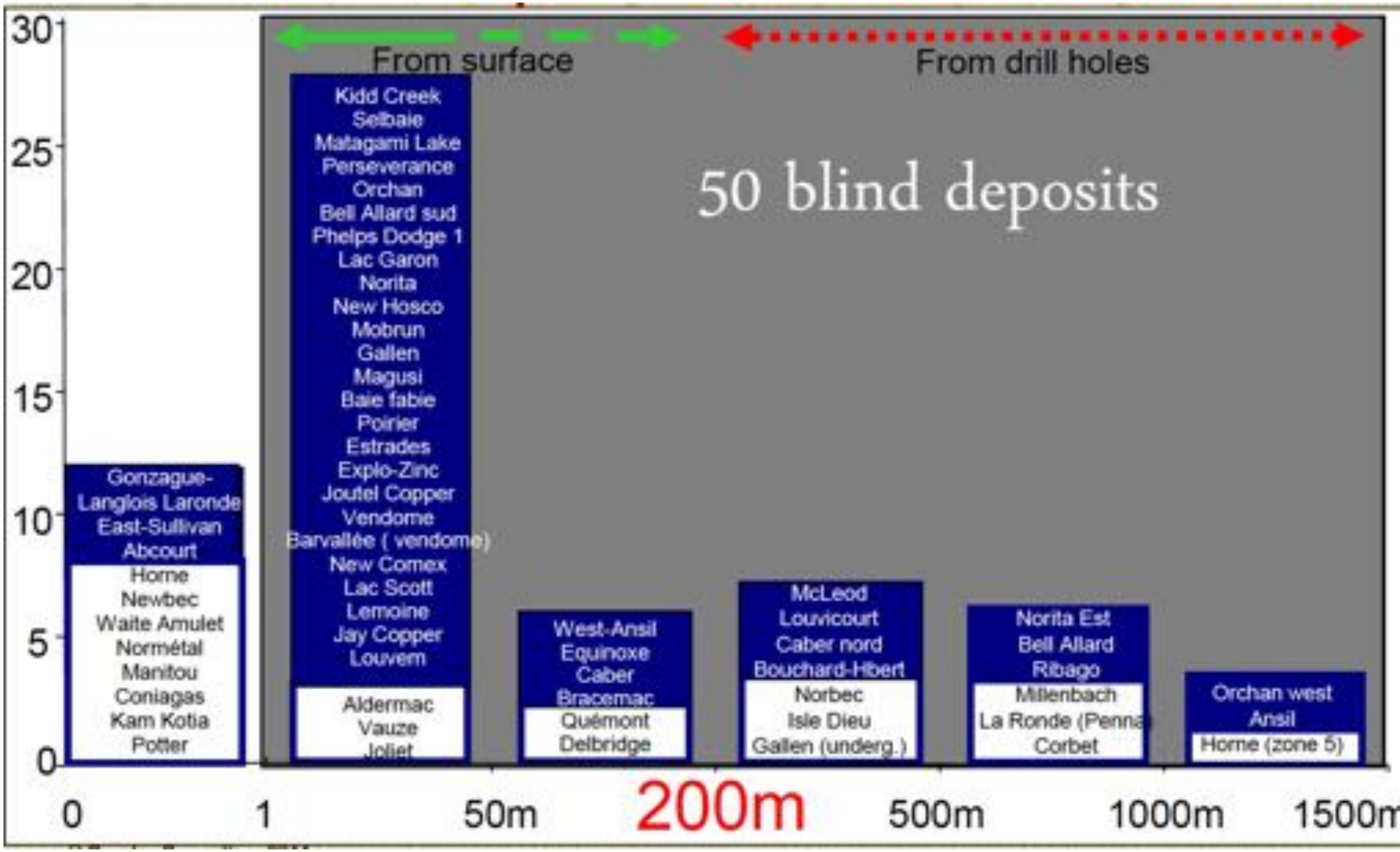
Gap



Depth to the top of 62 VHMS Deposits
From Allard and Witherley, 2010

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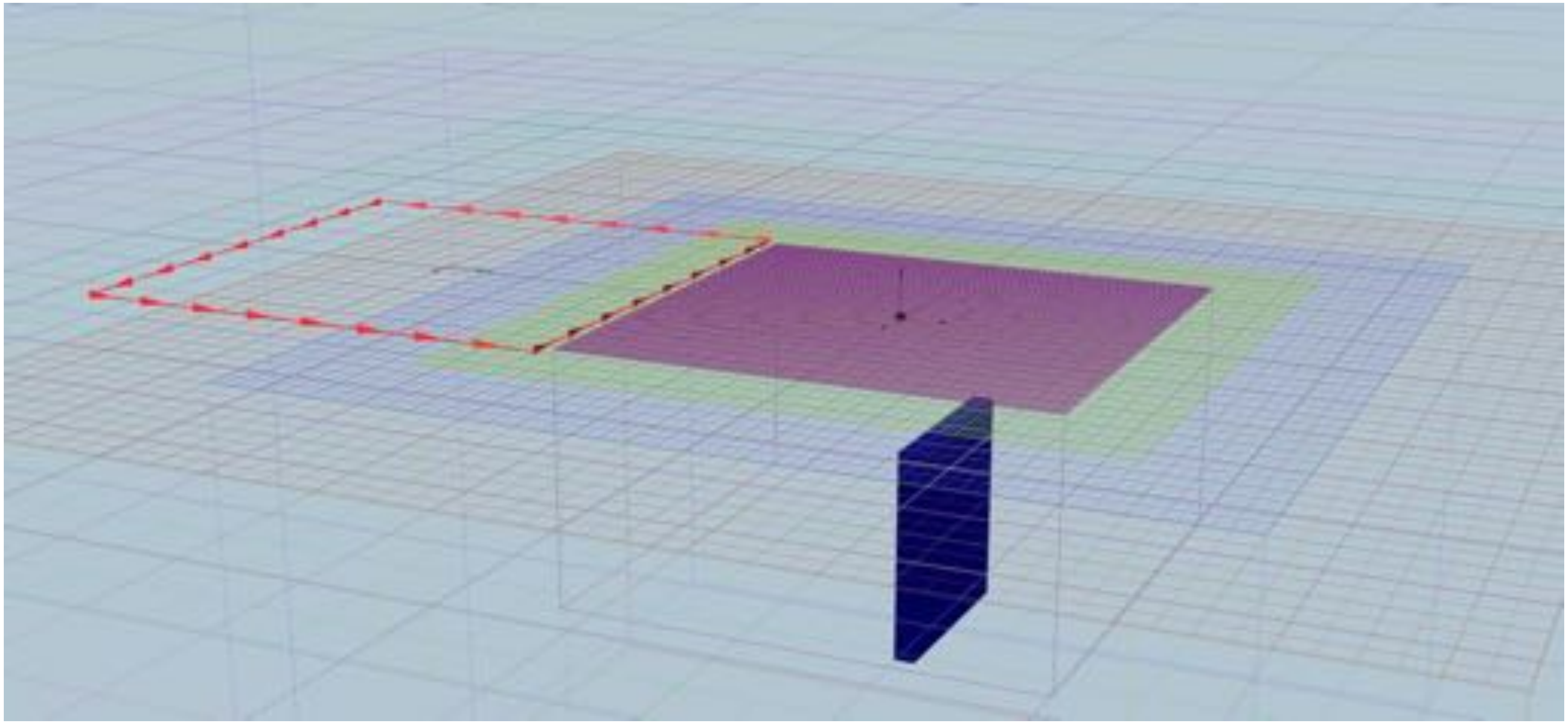
MGEM rho file mesh showing Conductor depth at 200m not connected to OB of 50m thickness



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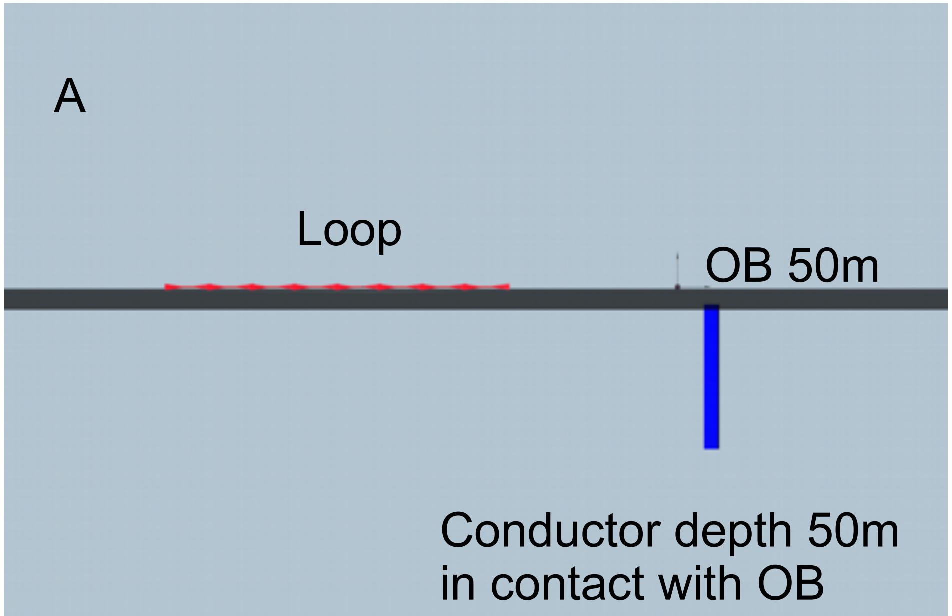
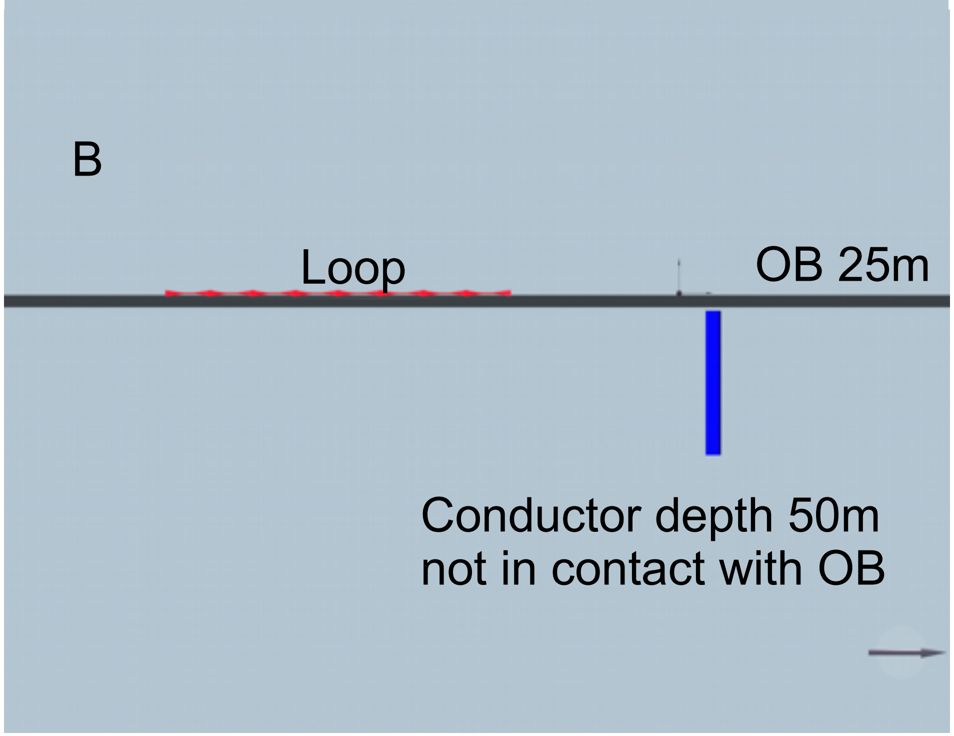




MGEM 3D models 2 Hz
Wide aperture (prim reduced)

A: 50m OB 50m depth in contact

B: 25m OB 50m depth no contact

C: 50m OB 200m depth

D: 25m OB 200m depth

E: as C, all channels

F: as D, all channels

MGEM 3D models 90 Hz
Narrower aperture (ch0 reduced)

G: 50m OB 50m depth in contact

H: 25m OB 50m depth no contact

I: 50m OB 200m depth

J: 25m OB 200m depth

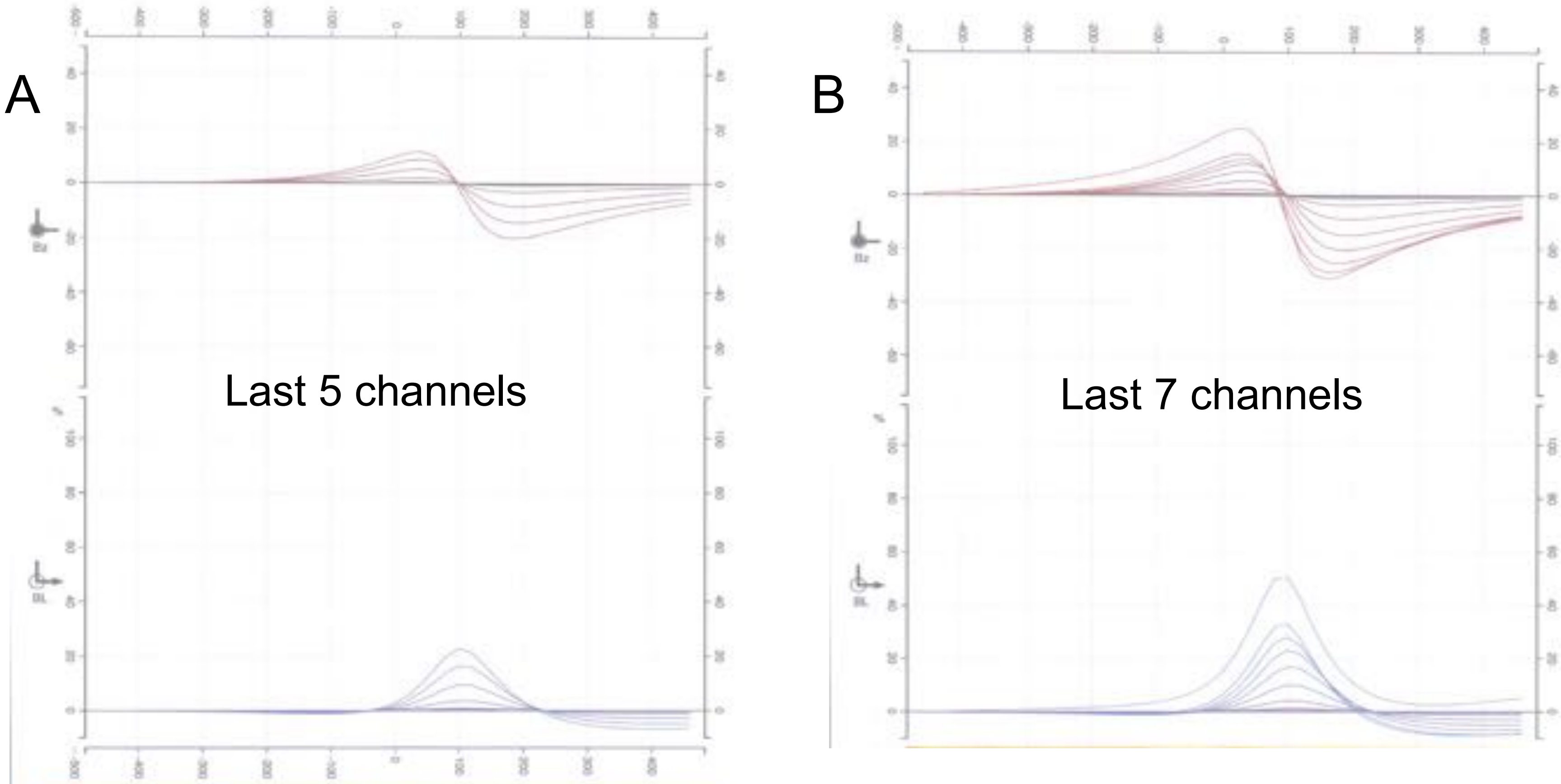
LAMONTAGNE GEOPHYSICS LTD GEOPHYSIQUE LTEE

MGEM modelling showing a late channel response from a UTEM survey (Base frequency 2Hz)

30 S/m Conductor – Depth 50m, Size 400m by 400m, and Thickness of 40m

(A) shows response with conductor in contact with OB of 50m (40 Ωm)

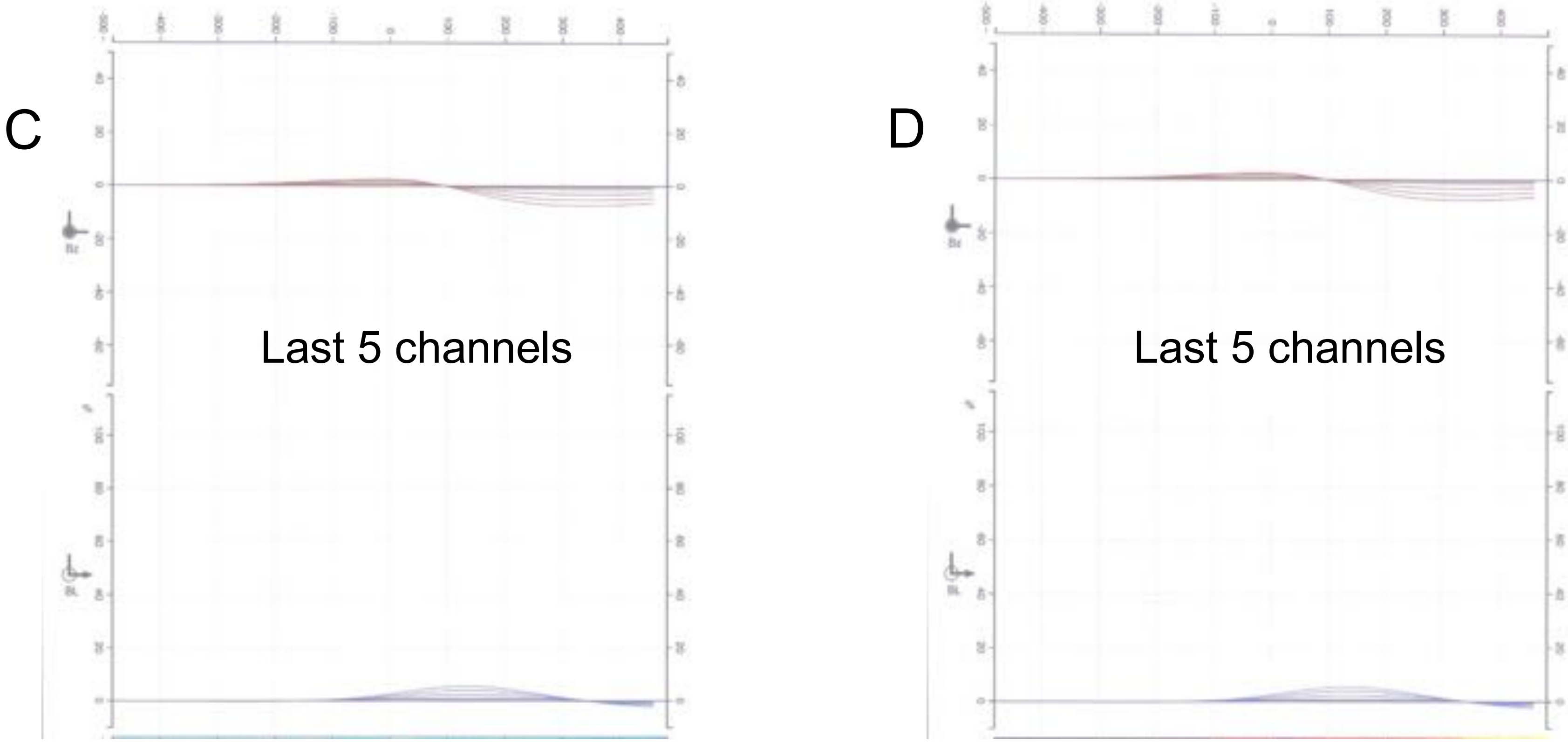
(B) shows response with 25m of overburden (20 Ωm) and no contact



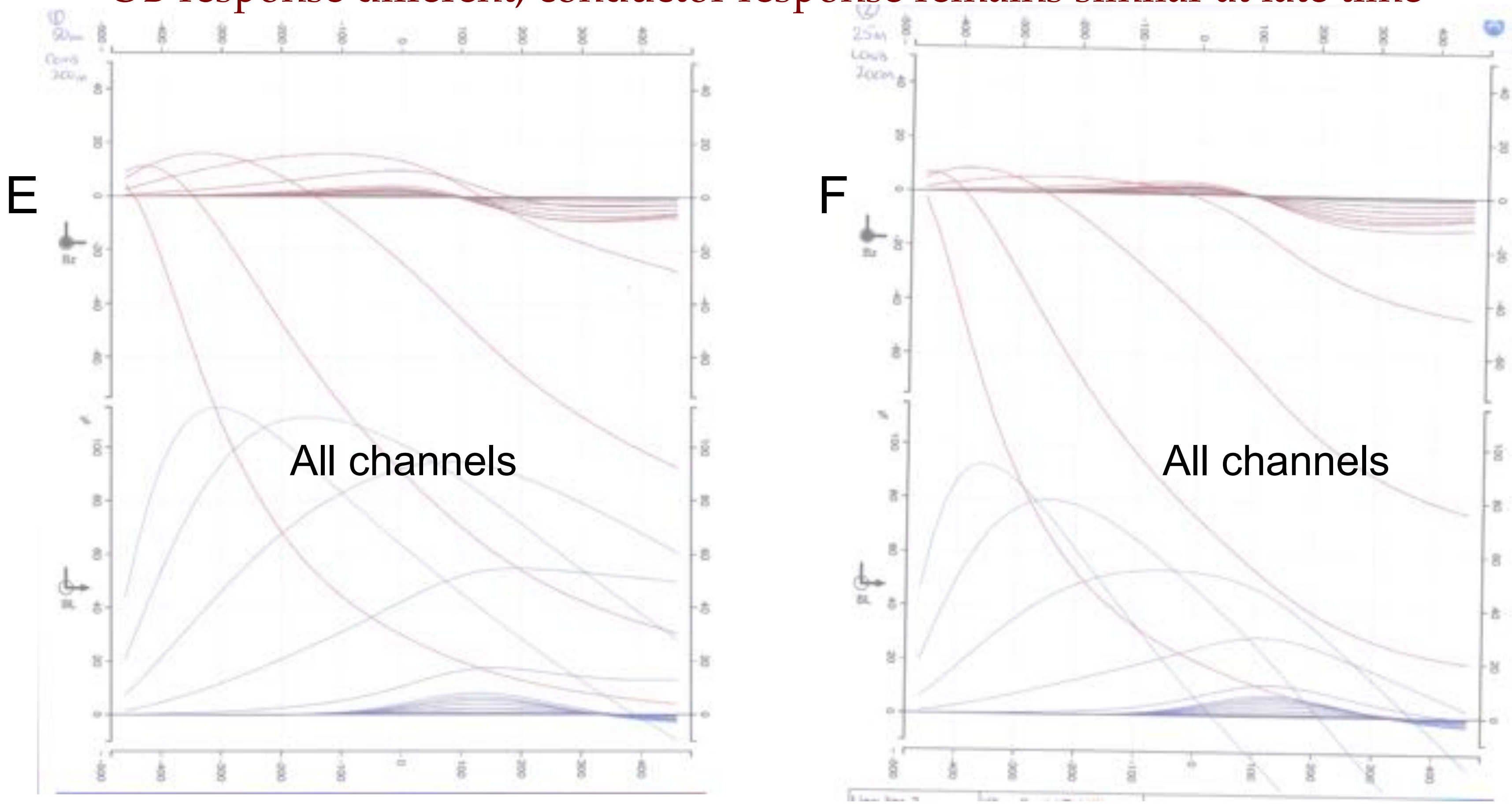
LAMONTAGNE GEOPHYSICS LTD GEOPHYSIQUE LTEE

MGEM modelling showing a late time response UTEM survey (Base frequency 2Hz)
30 S/m Conductor – Depth 200m, Size 400m by 400m, and Thickness of 40m
(C) shows response with conductor in contact with OB of 50m (40 Ωm)
(D) shows response with 25m OB (20Ωm), same conductor depth

Note: similarity in response, reduced by factor of 4 for depth 50m to 200m .



MGEM modelling of a UTEM survey (Base Frequency 2Hz)
showing early times of current channeling (OB) response
with late times clearly seeing the conductor which is well below the OB.
30S/m Conductor – Depth 200m, Size 400m by 400m, and Thickness of 40m
(E) shows response with conductor with OB of 50m (40 Ωm)
(F) shows response with OB of 25m (20 Ωm)
OB response different, conductor response remains similar at late time



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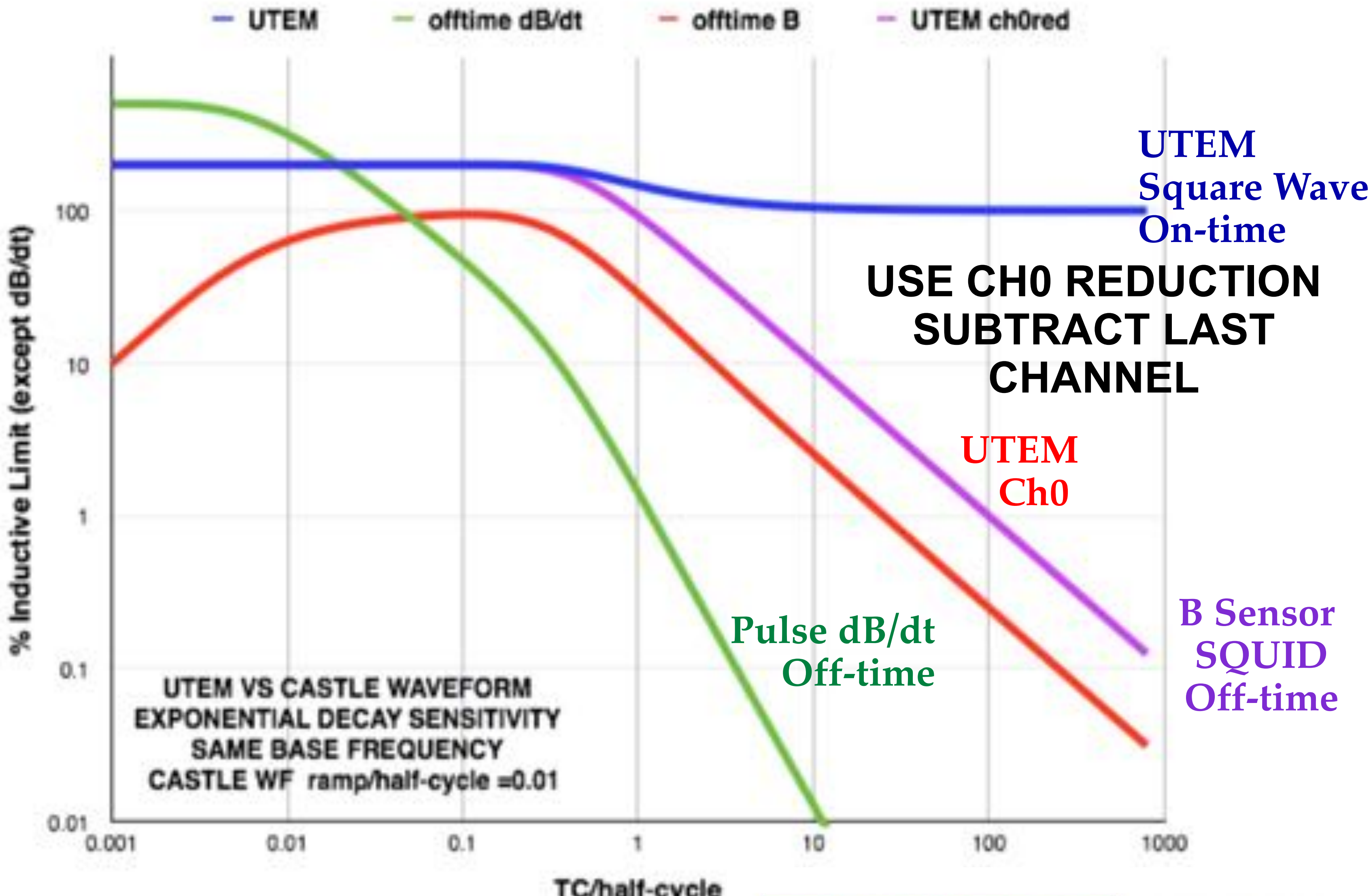
Sensitivity of Waveform/Sampling For Exponential Decays



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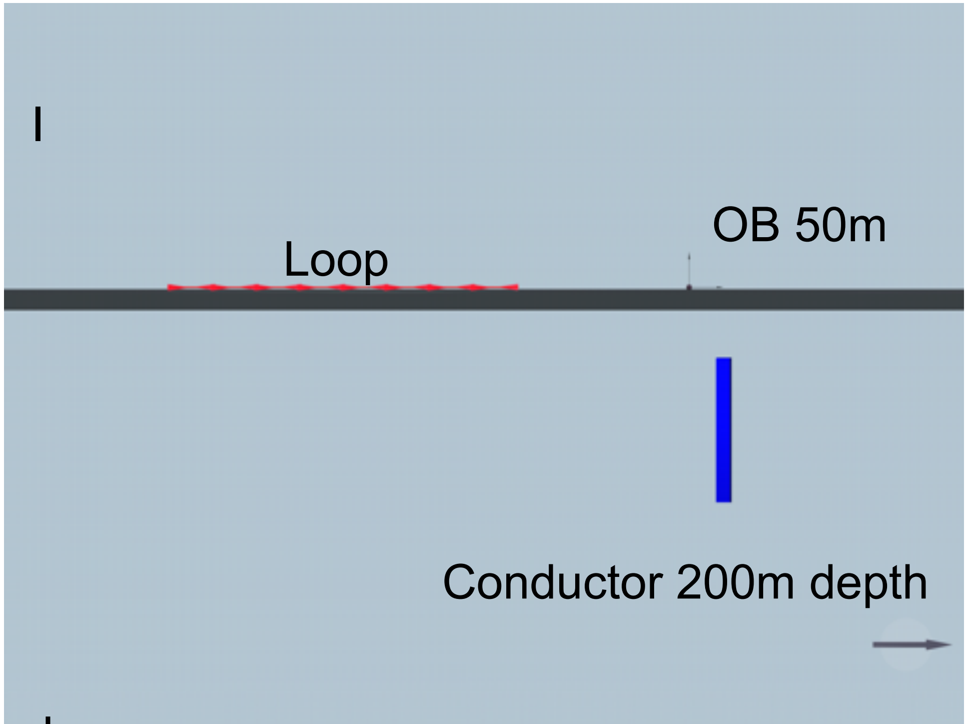

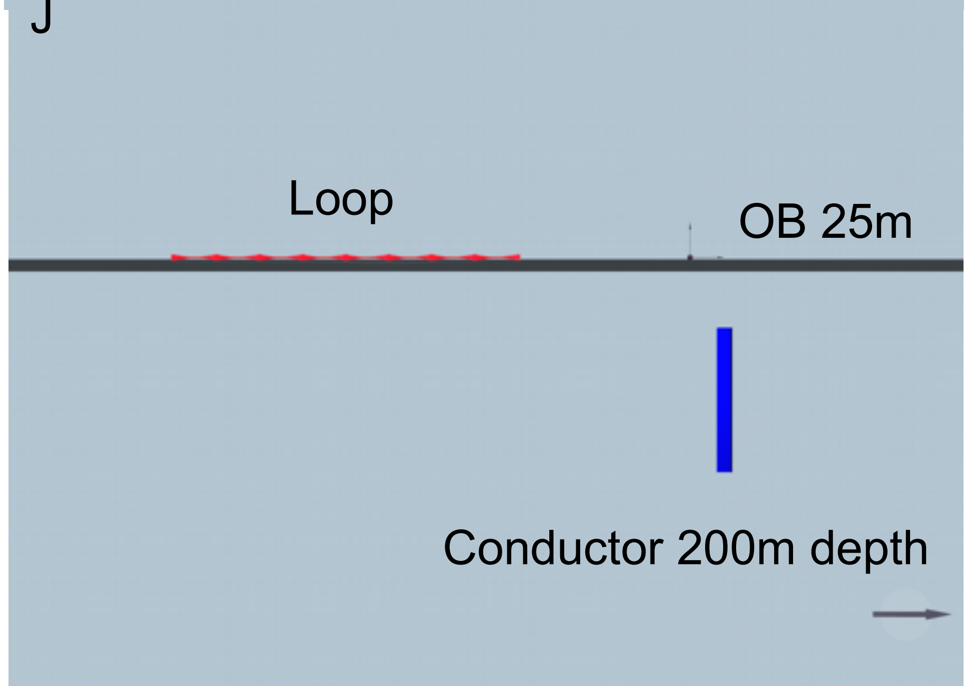

MGEM 3D models 2 Hz
Wide aperture (prim reduced)

A: 50m OB 50m depth in contact

B: 25m OB 50m depth no contact

C: 50m OB 200m depth

D: 25m OB 200m depth

E: as C, all channels

F: as D, all channels

MGEM 3D models 90 Hz
Narrower aperture (ch0 reduced)

G: 50m OB 50m depth in contact

H: 25m OB 50m depth no contact

I: 50m OB 200m depth

J: 25m OB 200m depth

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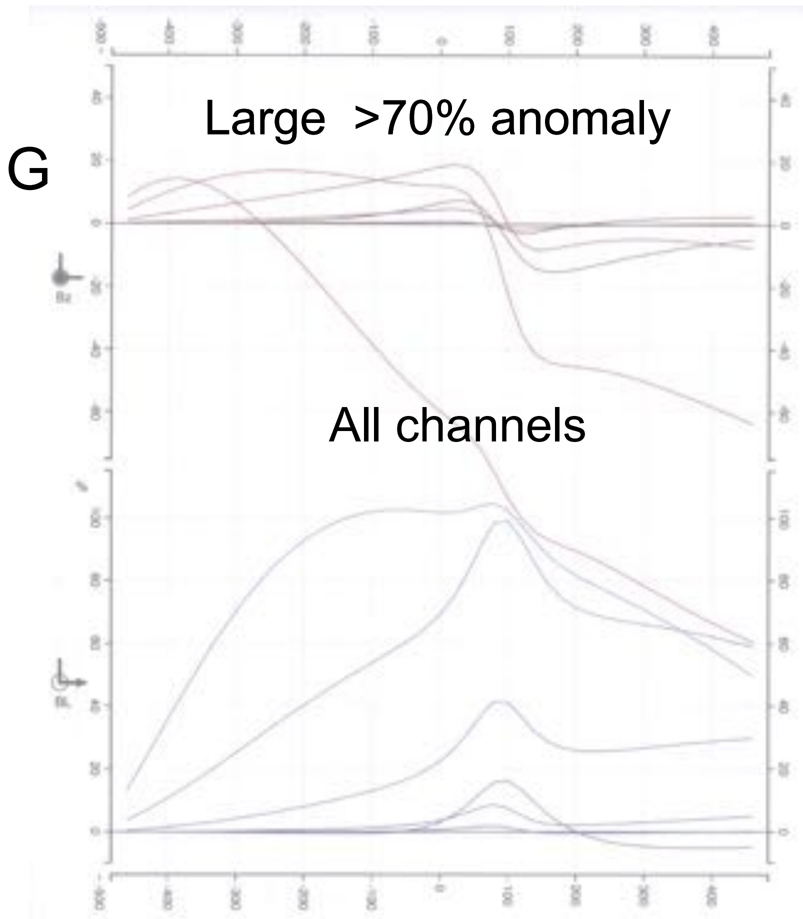
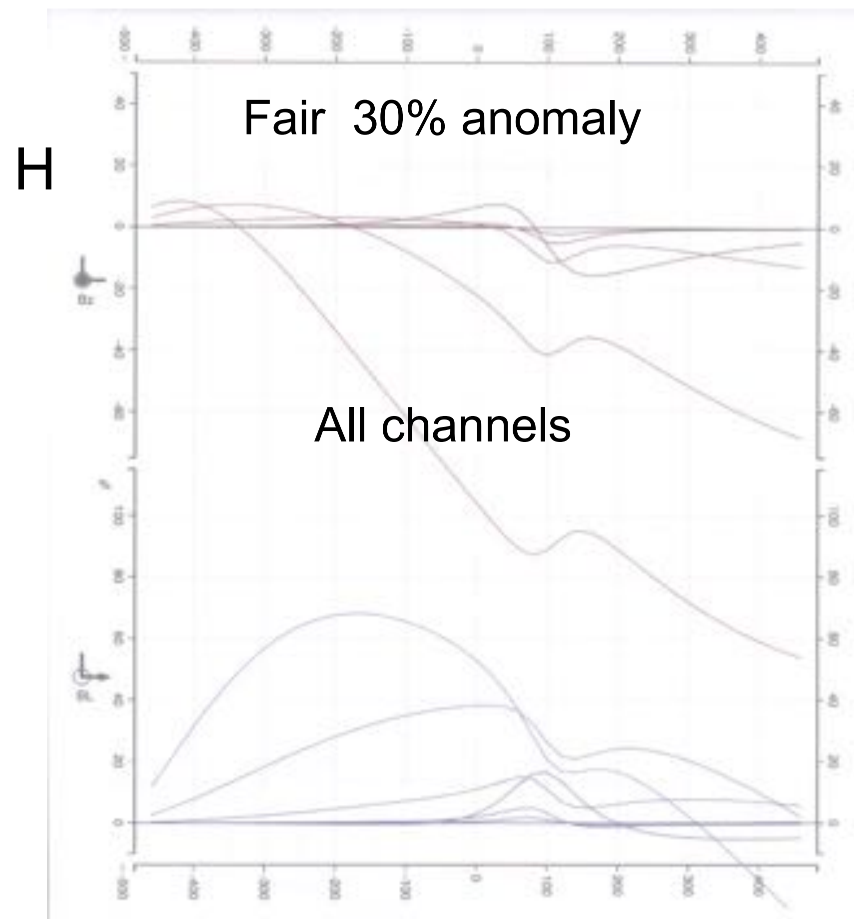
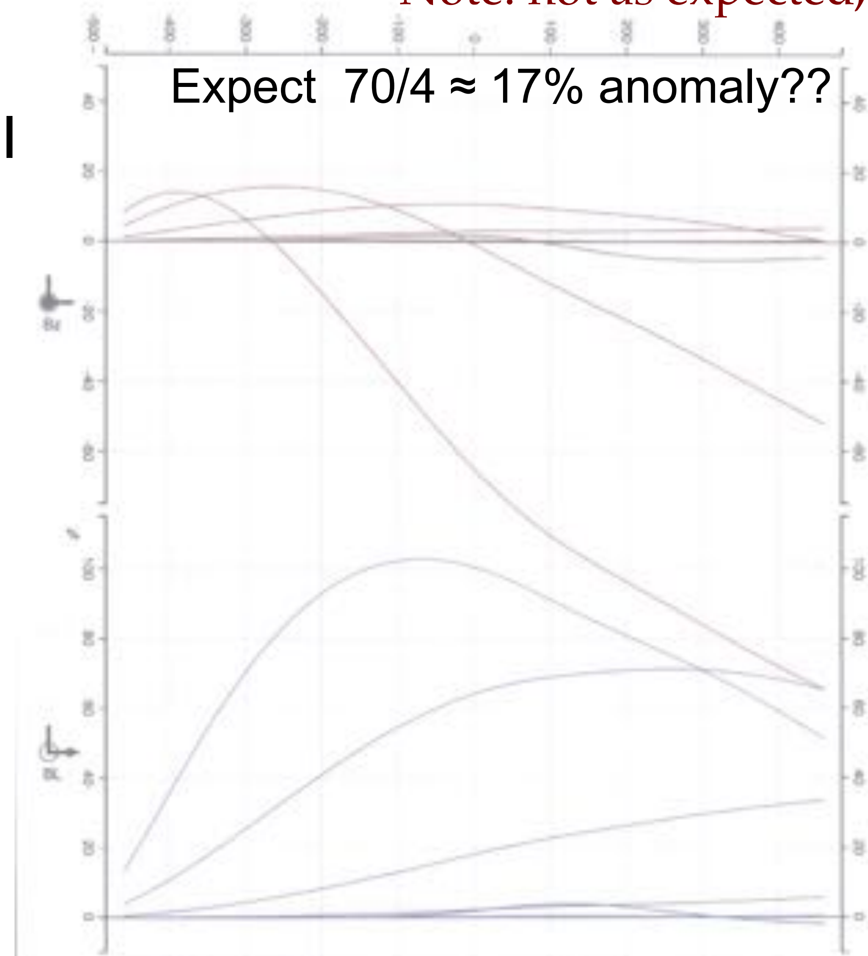
Narrower aperture MGEM modelling, (**ch0 reduced**, Base frequency 90Hz)
30S/m Conductor – Depth 50m, Size 400m by 400m, and Thickness of 40m
(G) shows response with conductor in contact with Overburden of 50m (40 ohm-m)
(H) shows response with 25m OB (25 Ωm) no contact with same conductor.

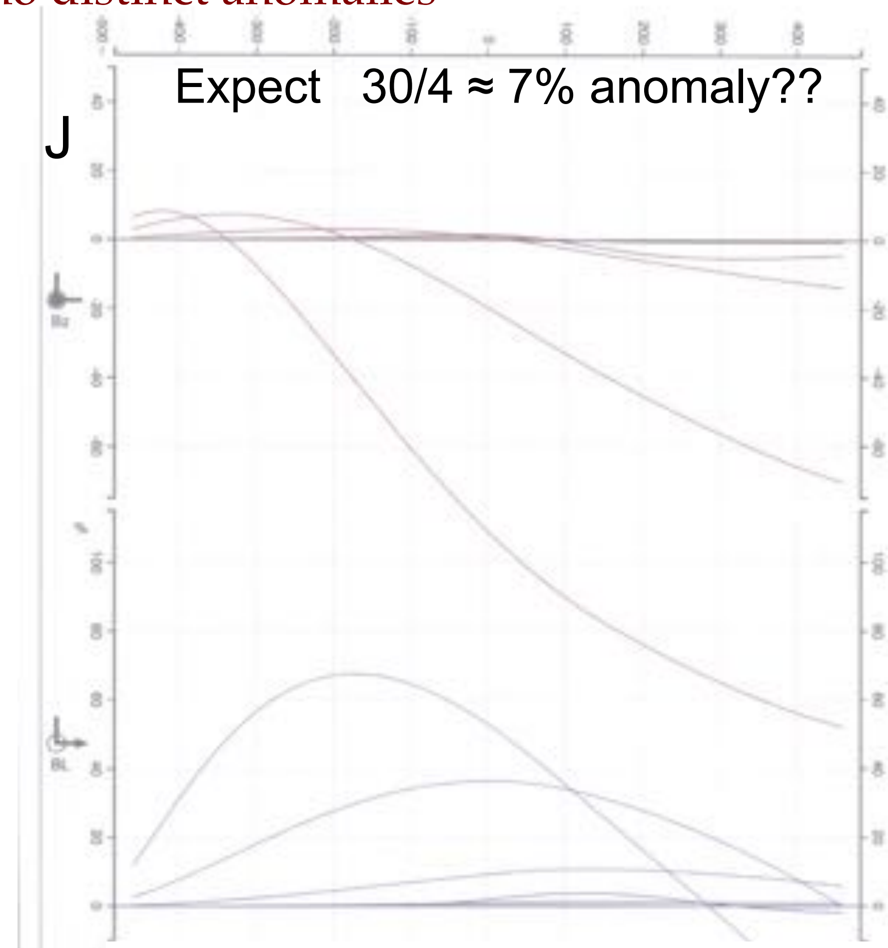




LAMONTAGNE GEOPHYSICS LTD GEOPHYSIQUE LTEE

Narrower aperture MGEM modelling (ch0 reduced, Base frequency 90Hz)
30S Conductor – Depth 200m, Size 400m by 400m, and Thickness of 40m
(I) response with conductor in contact with Overburden of 50m (40 Ωm)
(J) shows response not in contact with Overburden depth of 25m (20 Ωm)
Note: not as expected, no distinct anomalies





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A look back at traditional large loop coverage

Frequency =30 Hz
Half-cycle h = (1/60) s

Use our model shape of L = W = 10 d

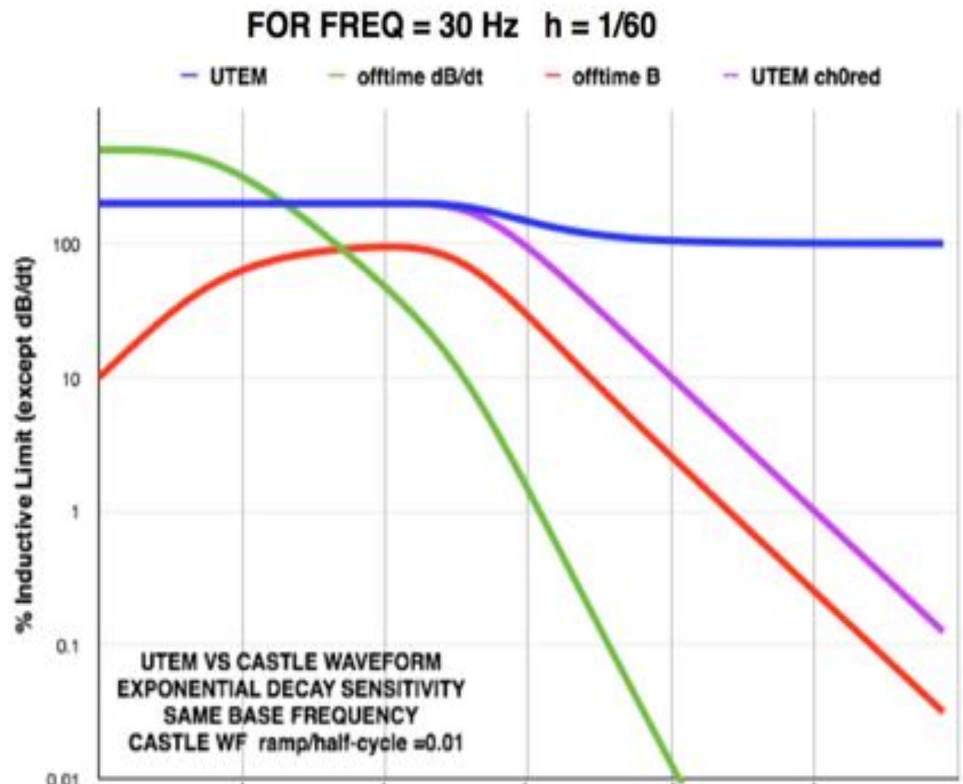
Decay time Td

$Td/h \approx 60\ \mu\sigma\ d\ L\ /\ 10 = 60\ \mu\sigma\ d\ L^2\ /100$

Tonnage

$M \approx 2.5\ L\ W\ d = 0.25\ L^3$
(rounded corners, density = 4)

Use these equations to express Td/h as mass (tonnage) for various conductivities σ



Ores with some cp/po	300	0.000	0.002	0.05	1.5	47
Chalcopyrite rich ores	30	0.002	0.05	1.5	47	1500
Median for ‘pyrite ores’	3	0.05	1.5	47	1500	
Poorly conductive pyrite ores (Mainly Parkhomenko)	0.3	1.5	47	1500		
	σ S/m	**Tonnage MT**				

Tonnage is for same shape as model L = W = 10 d

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Discussion

- Quo Vadis Exploration?
- Deep grid Drilling?
- The Gap! - 3D MGEM modelling explains part of the Gap problem.
- Is exploration through Volume Coverage the way forward?
- Measurement methods - Proven advantages for full spectrum broadband systems like UTEM provides the capability to **discriminate** between different conductors due to its **Uniform Sensitivity**.

- Intrinsically poor EM response!
- Summary shows Selbaie as the only poor conductor at **5S**
- Average conductance from case studies is **150S**
- Average strike **600m**, average length **400m**, average thickness **22m**
- Average tonnage **+20Mt**
- Ore bodies connected to the OB show enhanced responses
- Model parameters used seem well tuned.

- Likely that the ore deposit distribution is normal so empirically many more deposits remain to be found in both brown and green field environments.

- Deep reconnaissance surface EM? Large loops with low frequency.
- Is 100 km^3 enough?

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