GEOTECH LTD. AIRBORNE GEOPHYSICAL SURVEYS

Technical Session:
Exploratory Geophysics and Geochemistry

Helicopter EM (VTEM-ZTEM) Applications for Mineral Exploration

By Jean M. Legault* and Cristiano Foutoura**

*Geotech Ltd., Aurora, CA

**Geotech Aerolevatemento, Rio de Janeiro, BR

SimeXmin
IV SIMPÓSIO BRASILEIRO DE EXPLORAÇÃO MINERAL
IV BRAZILIAN SYMPOSIUM ON MINERAL EXPLORATION
Ouro Preto, 23 a 26 de maio de 2010

SIMEXMIN
Ouro Preto, BR
May 2010

Presented at SIMEXMIN 4TH Brazilian Symposium on Mineral Exploration
23-26 May, 2010, Ouro Preto, Brazil.

Outline

- Introduction
- VTEM-ZTEM Description & Features
- VTEM Case examples
    - Caber Cu-Zn (CA), Eagles Nest Cu-Ni (CA), Northern Empire Au (CA), Tusker Au (TZ), Nkran Au (GN),
- VTEM-ZTEM Case examples
    - Axis Lake Cu-Ni (CA), Cinco de Mayo Pb-Zn-Ag (MX)
- ZTEM Case examples
    - Shea Creek U (CA), Pebble Cu-Ag (US), Lalor Lake Zn-Au (CA)

Conclusion

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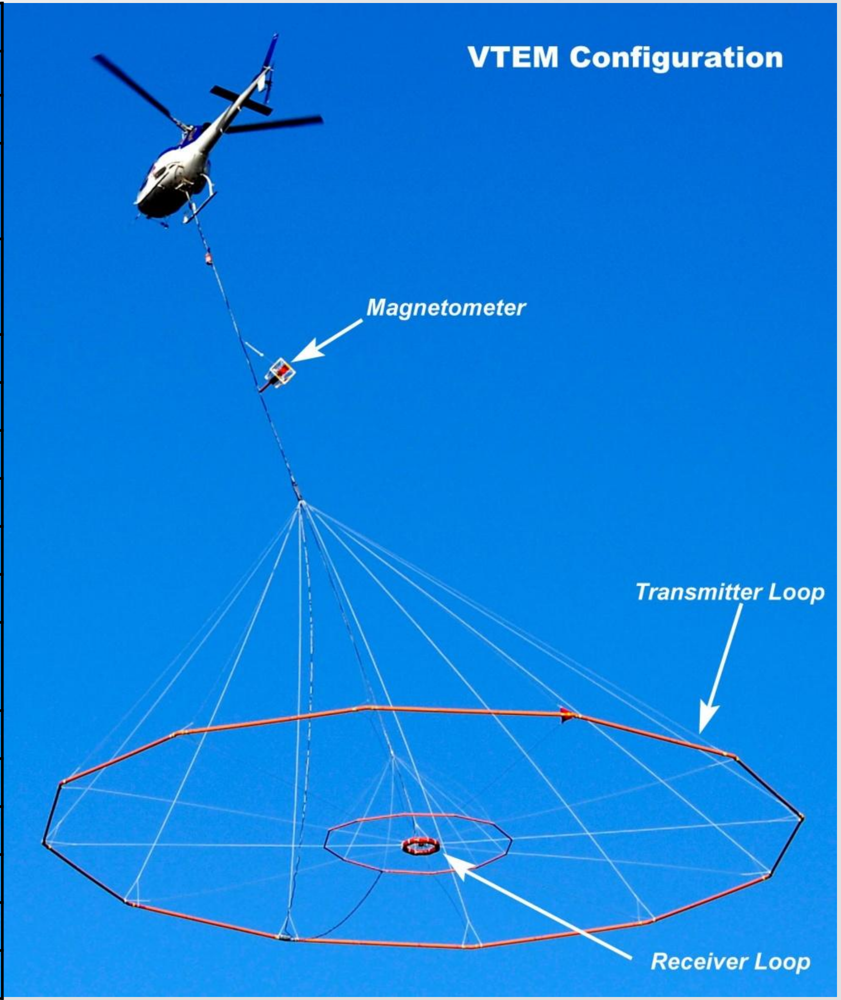
Part 1: VTEM – Versatile Time Domain electromagnetics

Award Winning and Industry Leading Airborne EM Technology

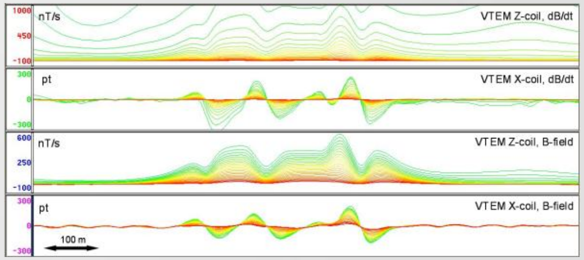
The VTEM System

Parameter	VTEM[26]
Base Frequency	25 Hz/30Hz
Waveform	Trapezoid
Current	Maximum: 310 A (4.4ms pulse) 200 A (7.5ms)
Peak dipole moment	Maximum: 625 000 Am^2 (4.4ms) Typical: 425 000 Am^2 (7.5ms)
Tx loop diameter (area)	26 m (540 m^2)
Tx number of turns	4
Survey speed	80 km/h
Tx/Rx Clearance	30 m
Tx turn-off time	1.1 ms
Tx Pulse On Time	Programmable 4.6 to 7.5 ms
Rx Time gates	2009: 28 (0.120–7.83 ms) 2010: 35 (0.083–8.08ms)
Rx coil diameter, m	1.2 (Z) & 0.32 (X)
Rx Effective Area, m^2	101.1 (Z) & 19.7 (Z)
Receiver sampling	0.1sec (approx. 2-3m/sample)
Magnetometer	Optically pumped caesium vapour
Mag Clearance	60 m
Mag sensitivity	0.02nT (0.001nT base)



Outlining VTEM System Specifications and Key Elements

VTEM – Technical Highlights



- 25/30 Hz base frequency (permits long decay measurements), sampled using up to 50 channels with 2010 acquisition system
- 26m x 4 turn Transmitter coil (the largest diameter loop available on any airborne geophysical platform), 35m for $VTEM^{35}$
- Large Dipole moment (425,000 Am^2 for $VTEM^{26}$ / >950,000 Am^2 for $VTEM^{35}$) with Extremely Low System Noise (<0.0003 pV/Am^4)
- Deep Penetration (arguably best of HTEM systems), 300-400m for shallow dipping targets, >750m proven (Athabasca Basin, SK, CA)
- Focused footprint to also discriminate smaller targets (i.e., kimberlites, breccia pipes, paleochannels, etc.).
- Superior "Repair or Replace" Time (few hours)
- Concentric Transmitter–Receiver geometry ensures accurate anomaly location (response symmetry same regardless of survey direction), Z & X (+/- Y) sensors
- VTEM is widely considered the best Helicopter TEM massive sulphide detection & imaging tool; with proven "fly-to-drill" capability from high accuracy GPS positioning, at 0.1samples/sec. equals 2-3m between data points.

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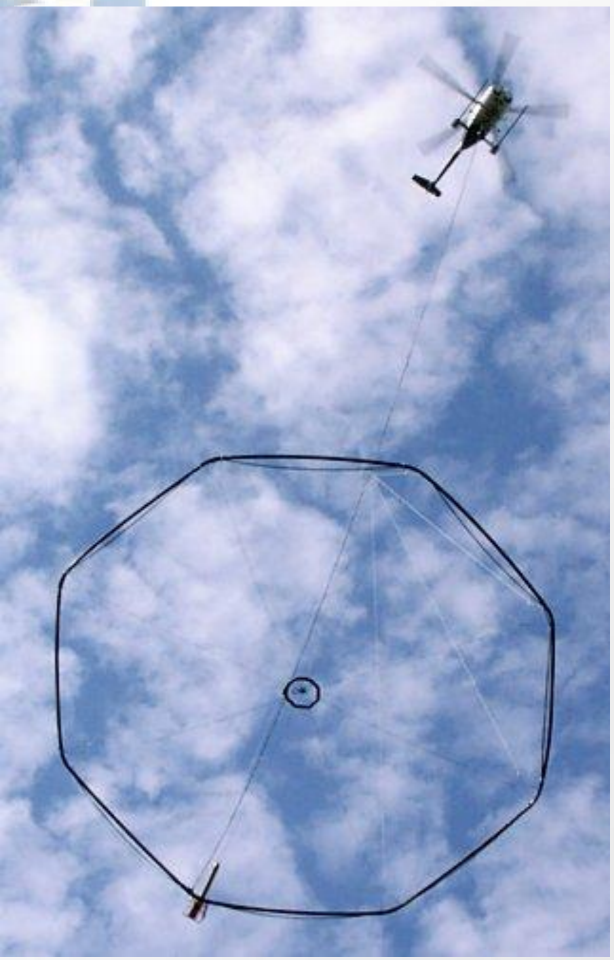
VTEM Continuous Evolution



2002		2007
18 m	diameter	**26 m**
120 000 Am^2	Dipole moment	**425 000* Am^2**
-	System of noise reduction	**+**
Z	Multi component recording	**ZX**
-	Compensation of primary EM field (for B-field calc.)	**+**

*** 425K for pulse 7.5 msec, 600K for pulse 4.6 msec**

Showing Improvement and Innovation in VTEM System from Inception to Present

Introducing VTEM^{35}

(Deepest Seeking HTEM System in Industry)

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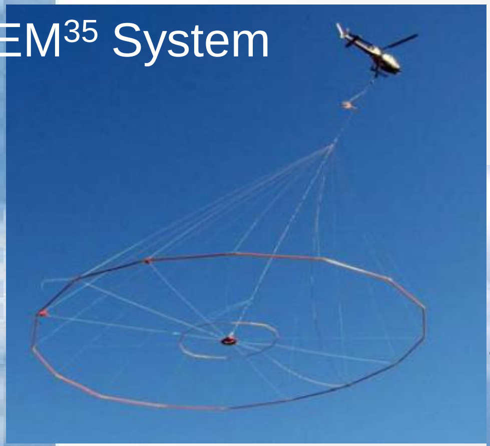
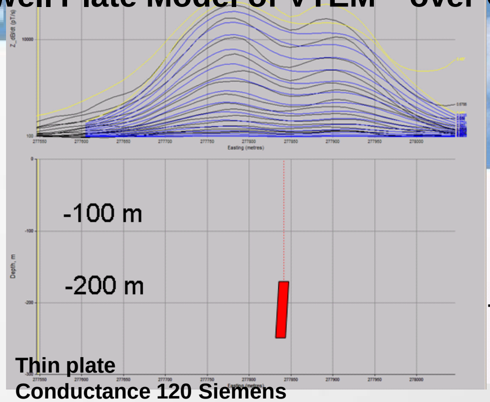
- VTEM^{35} is the latest, most powerful and lowest noise VTEM (versatile time-domain electromagnetic helicopter borne) system developed by Geotech Ltd. With the 35 m diameter transmitter loop VTEM^{35} generates a 1,000,000 NIA peak dipole moment at 30Hz – greater than 2x more than previously.
- The new 2010 VTEM data acquisition system (full streaming data) also provides more time gate windows (50channels), across a wider range (5 microseconds to 12 milliseconds), at significantly higher S/N (<0.0003 pV/Am^4) reinforcing the VTEM^{35} as the premier helicopter EM system worldwide.

VTEM^{35} System

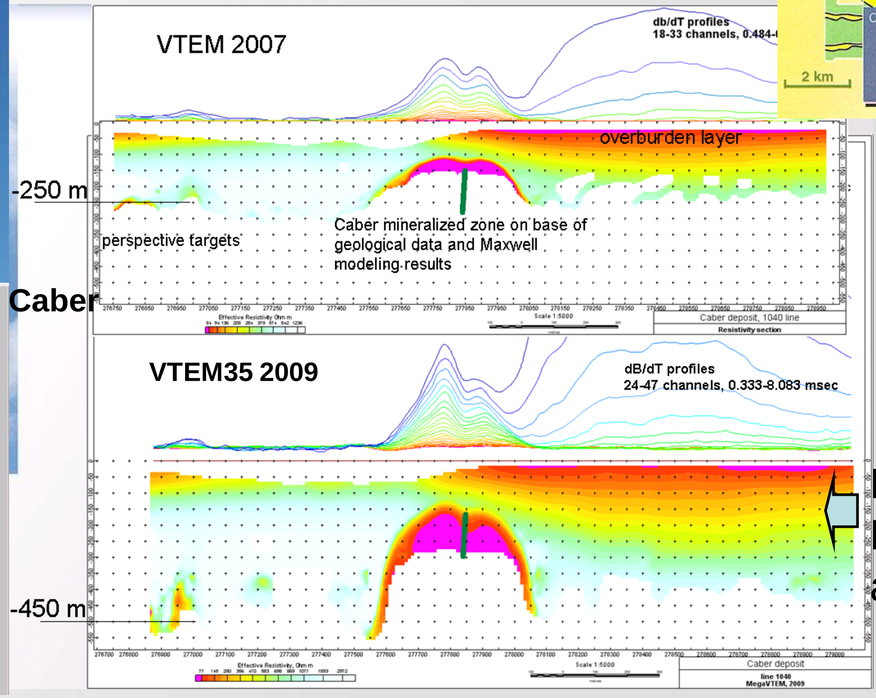


Maxwell Plate Model of VTEM^{35} over Caber

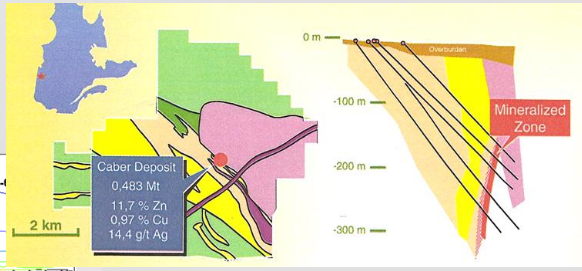


Thin plate
Conductance 120 Siemens
Depth 120m Depth extent 130m
Dip 85deg S Strike length 250m

VTEM^{26} vs. VTEM^{35} over Caber



Geology of Caber VMS Deposit, QC



TEM Depth of Investigation*

(Near-field – dB/dt Systems)

$$\delta_{TEM} \approx 0.55\left[\frac{nIA}{\sigma\eta_V}\right]^{1/5}$$

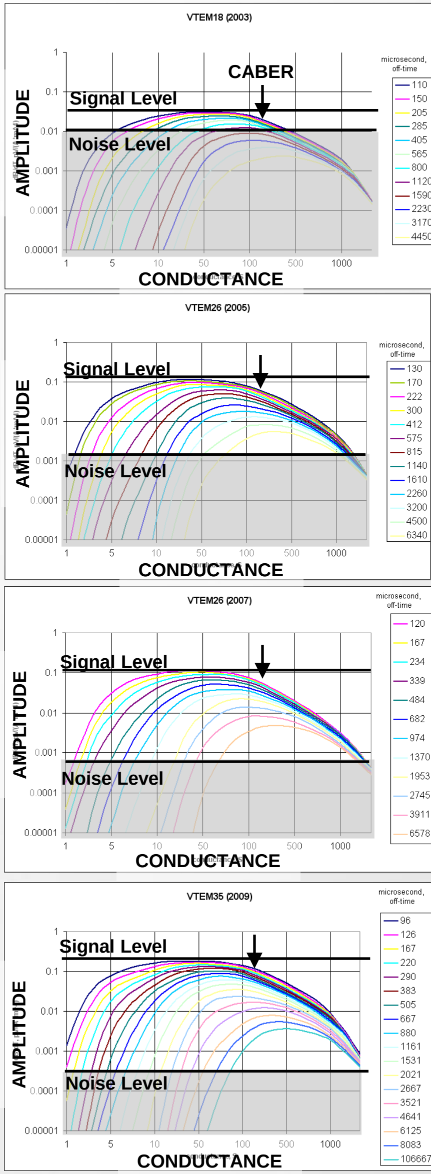
Dipole Moment (nIA), *Host Conductivity* (σ), *System Noise* (η_V)

Notice increased Depth Penetration and Improved Response

Showing VTEM^{35} System over Caber VMS Deposit (CA)

VTEM Continuous Evolution

Off-Time dB/dt Amplitude vs. Conductance



VTEM18 - 2003

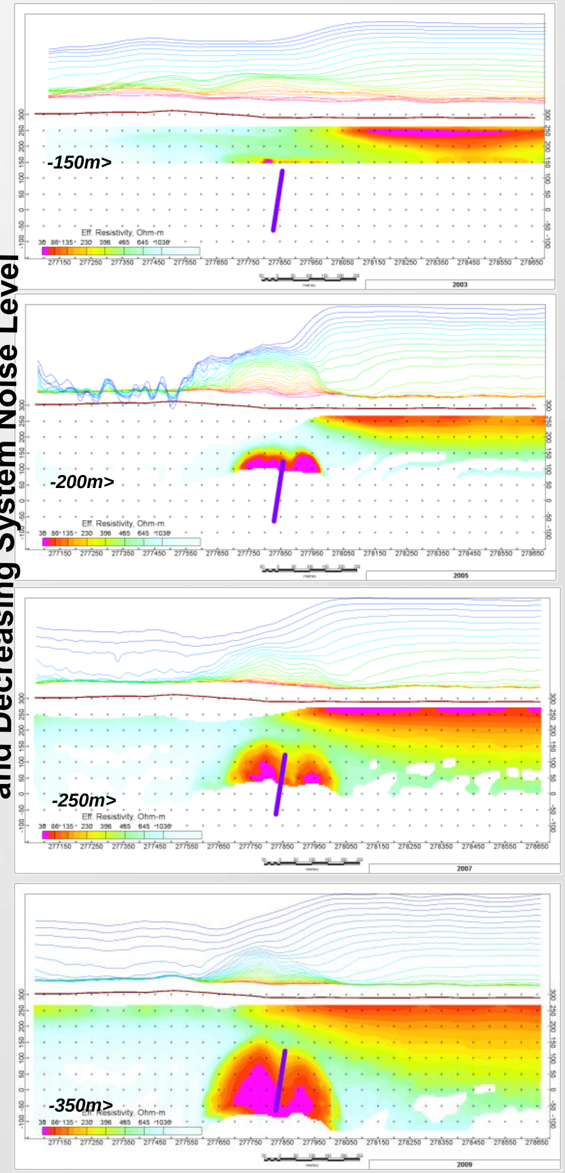
VTEM26 - 2005

VTEM26 - 2007

VTEM35 - 2009

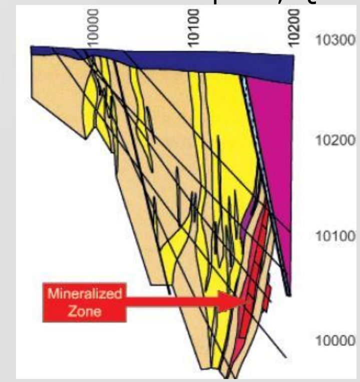
Progressively Increasing Signal Strength and Decreasing System Noise Level

RDI Resistivity-Depth Image and Caber Plate Model

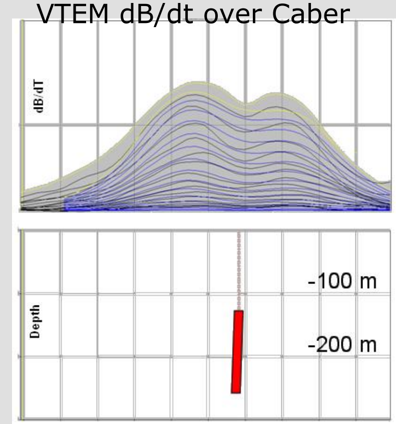


Equals Progressively Increasing Depth Penetration

Geologic Cross-section of Caber VMS Deposit, QC



Maxwell Plate Model for VTEM dB/dt over Caber



Thin plate
Conductance 120 Siemens
Depth 120m Depth extent 130m
Dip 85deg S Strike length 250m

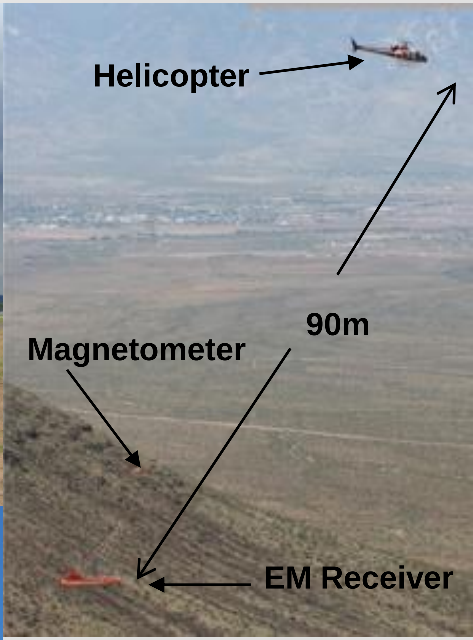
Showing How Improvements Affected Depth of Investigation between 2003 & 2009 VTEM Systems

Part 2: ZTEM – Z-axis Tipper electromagnetics

Introducing Airborne AFMAG (audio-frequency magnetic) Technology

Specifications

Parameter	ZTEM
Transmitter	None required (Passive EM method)
Sampling Frequency	A/D = 2000 Hz A/D (0.0005sec) Output = 2.5Hz (0.4s ~10m/sample)
Receiver	Bird = Hz (Vertical Dipole), Base = Hx-Hy (Horizontal Dipole)
Survey speed	80 km/h
Rx Clearance	50 m (nominal)
Rx coil diameter	Mobile = 7.2m Base = 3.5m
Rx Frequencies	32, 45, 90, 180, 360 Hz (+/- 720Hz)
Rx Derived Measurements	Tx (Hz/Hx) & Ty (Hy/Hz) Tippers (via Tensor FFT)
Rx Transfer Functions	In-Phase and Quadrature
Nominal Noise floor	<1%
Skin Depth Penetration	~1km-3km for 1k Ω-m avg. Host ~300m-1km for 100 Ω-m avg. Host

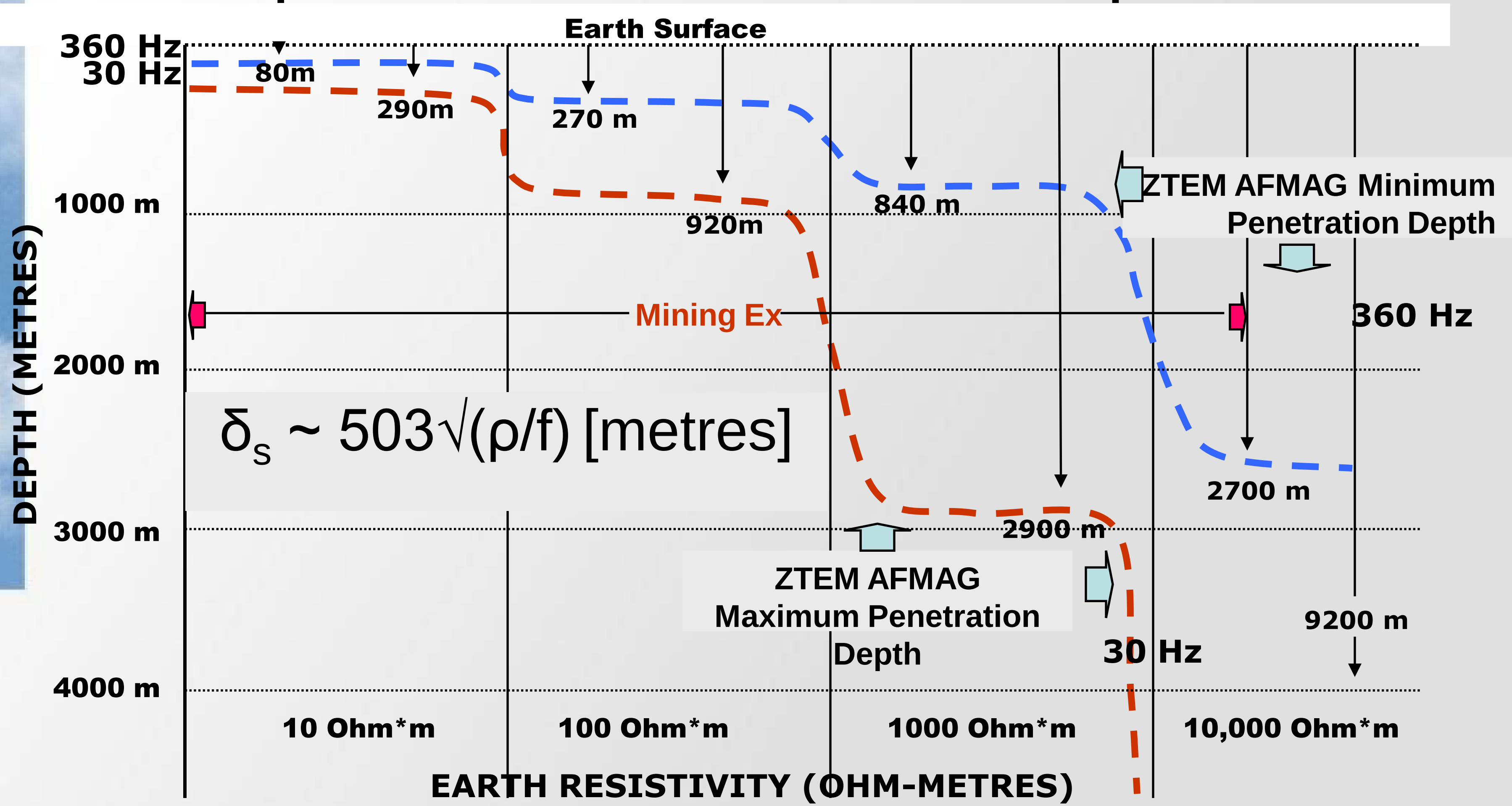


- ***In ZTEM only Vertical component (Hz) of AFMAG field is measured in receiver coil.***
- ***The horizontal (Hx-Hy) primary fields are measured at the base-station.***
- ***This is a distinct advantage in terms of data quality (>10x improvement in S/N over AFMAG).***

ZTEM - Features

- Excellent sensitivity to lateral resistivity contrasts, for example fault-fracture zones, clay-alteration, silicification, rock permeability/porosity water, etc. – but also sensitive to absolute conductivity, such as graphitic shales, massive sulphides, etc.
- 30-720Hz frequency Bandwidth provides for deep penetration, makes ZTEM a depth-"sounding" and profiling tool; mid-low frequency range permits near-4 season survey capability.
- Superior Exploration Depth – easily over 2000 metres in resistive crystalline rocks, likely up to 1000m in more conductive sedimentary settings.
- Relative insensitivity to flight-height variations (due to relatively larger primary field penetration depths, small $1/R^2$ fall-off rate)
- Most importantly, the uniform, plane-wave nature of the natural EM fields permits fast 2D-3D forward & inversion possible on PC, makes ZTEM unique Geologic Mapping Tool.

ZTEM Features: Depth Penetration
Simplest Case: 1D Skin Depth Rule



MT PLANE WAVE SKIN DEPTHS in 1D HALF-SPACE

*(Ref. Vozoff, 1972)

ZTEM Features: Depth Penetration

Athabasca Basin (CA) ZTEM vs. Helicopter TEM Survey Comparison

(over Graphitic Argillite Buried at 500-700m Depth below Paleozoic Sandstone Cover)

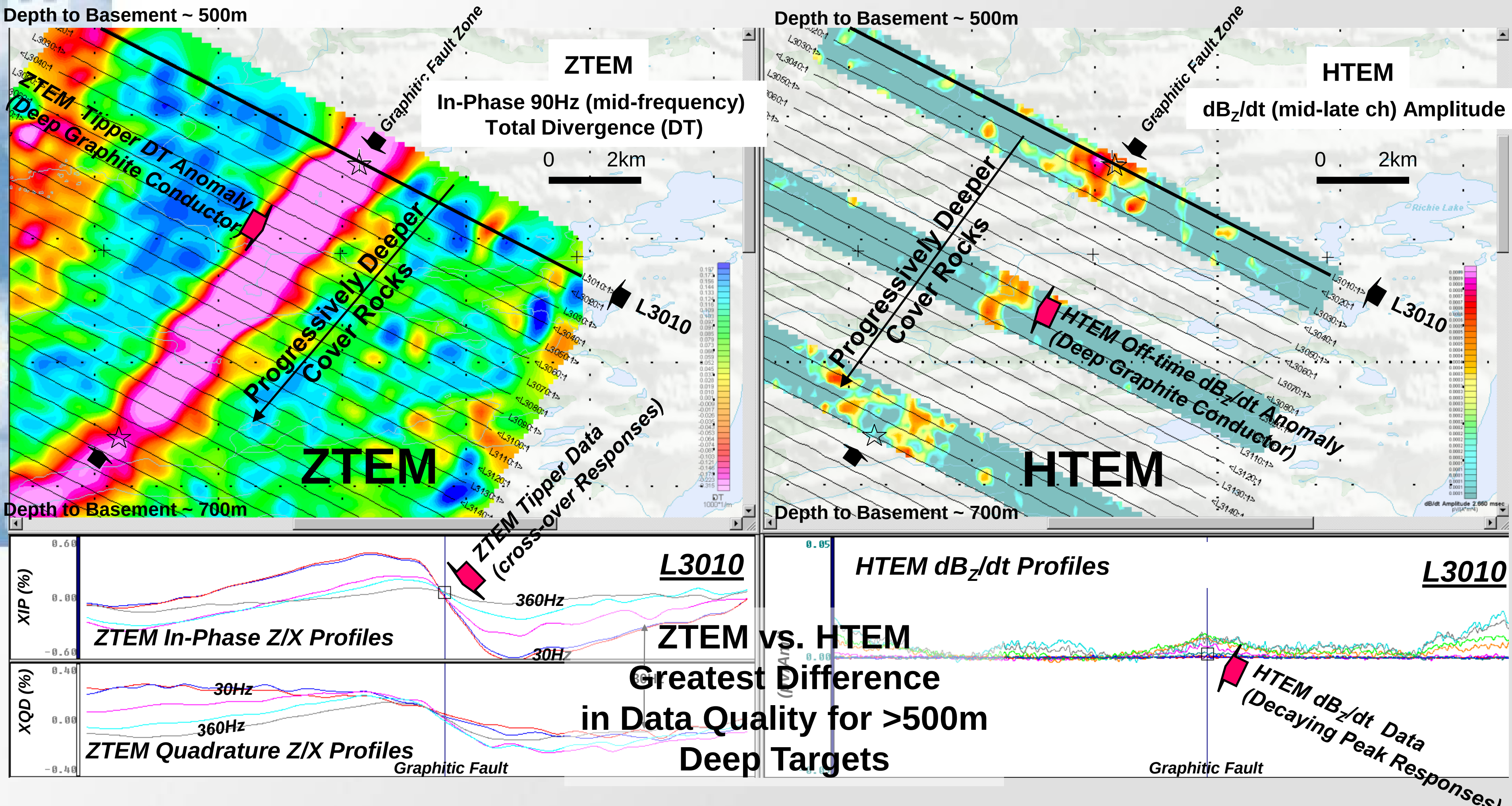


***Figure:** (Above) Comparison between ZTEM In-Phase 90Hz DT results (left) and HTEM mid-late-channel off-time decay amplitude grid contours (right). (Below) ZTEM In-Phase and Quadrature Z/X (In-line) data (left) and HTEM dB_Z/dt data (right).*

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Part 3: VTEM – Versatile Time Domain electromagnetics

Mineral Exploration Case Study Examples

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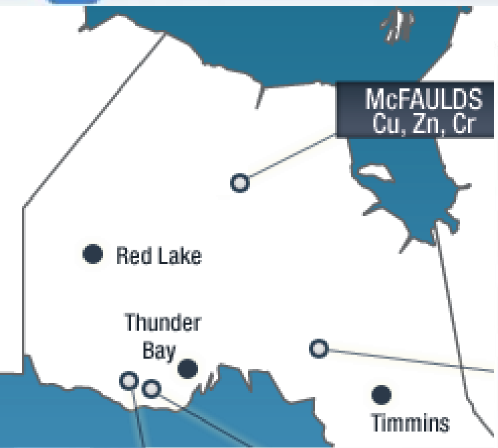
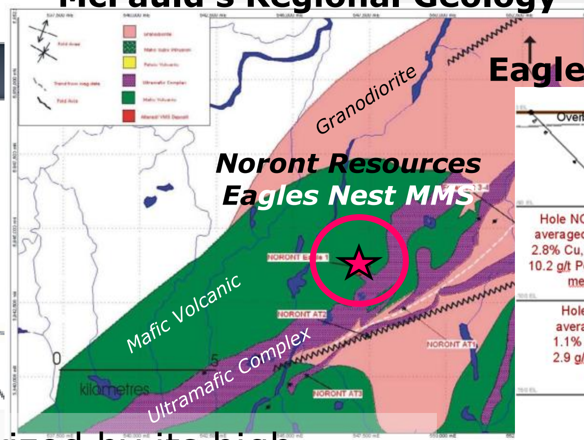
VTEM for MMS Magmatic Cu-Ni Massive Sulphides: Eagles Nest, McFaulds Lake, ON

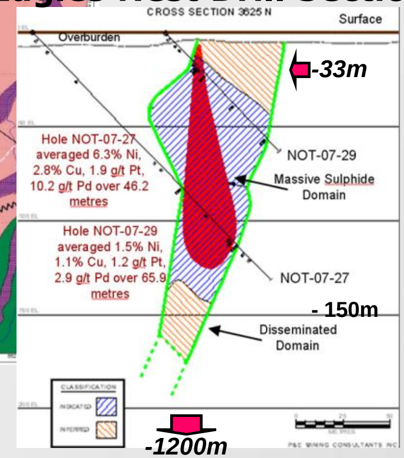
(6.9Mt indicated @ 3.6% Ni, 0.95% Cu, 1.3g/t PT)



McFauld's Regional Geology

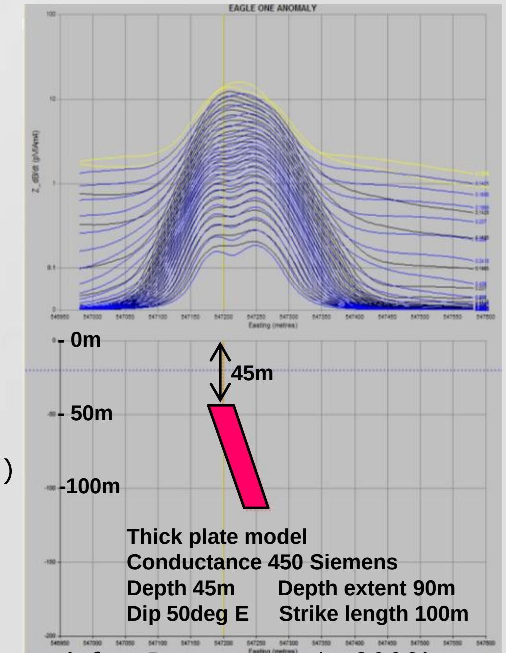


Eagles Nest Drill Section



(courtesy Noront Resources, 2007)

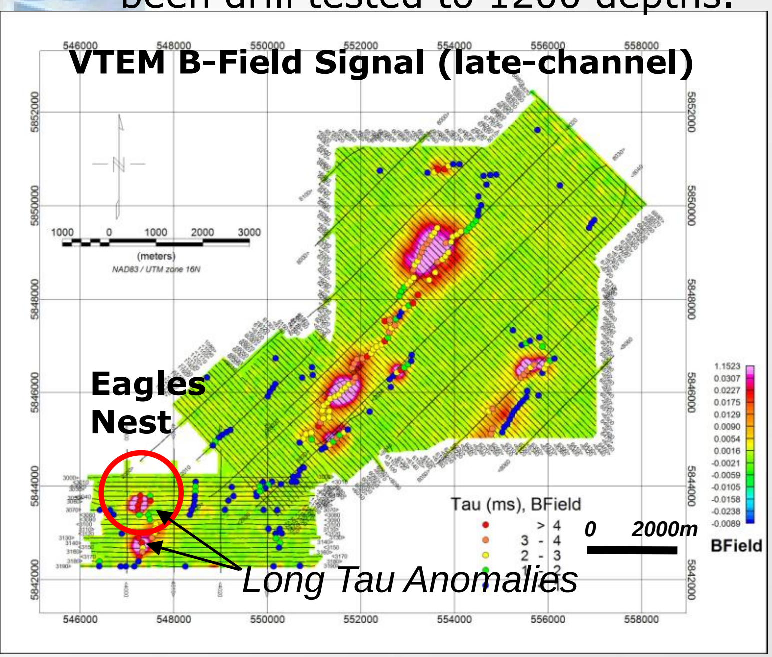
Maxwell 2.5D VTEM Model



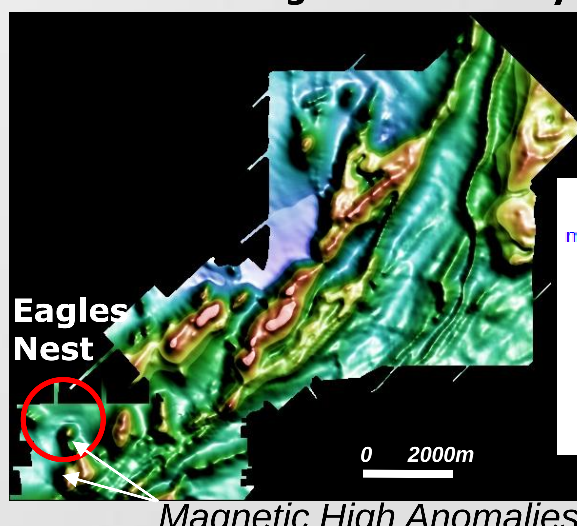
(after Bournas et al., 2009)

Eagles Nest is characterized by its high conductance (long Tau) and high magnetic susceptibility. The deposit has been drill tested to 1200 depths.

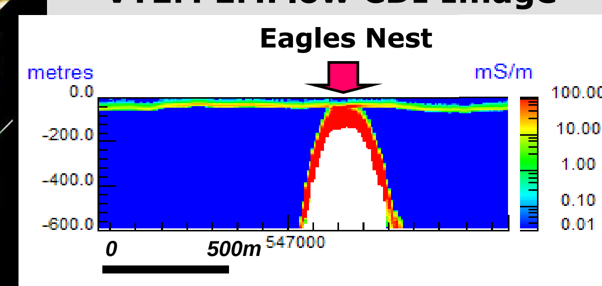
VTEM B-Field Signal (late-channel)



VTEM Total Magnetic Intensity



VTEM EMFlow CDI Image



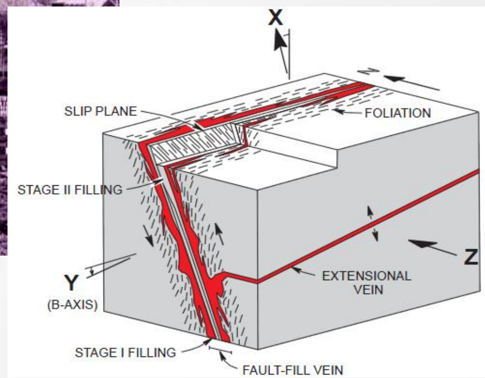
(after Bournas et al., 2009)

(courtesy Noront Resources, Fancamp Resources & Freewest Resources, 2009)

VTEM for Gold: Northern Empire Mine, Beardmore, ON CA

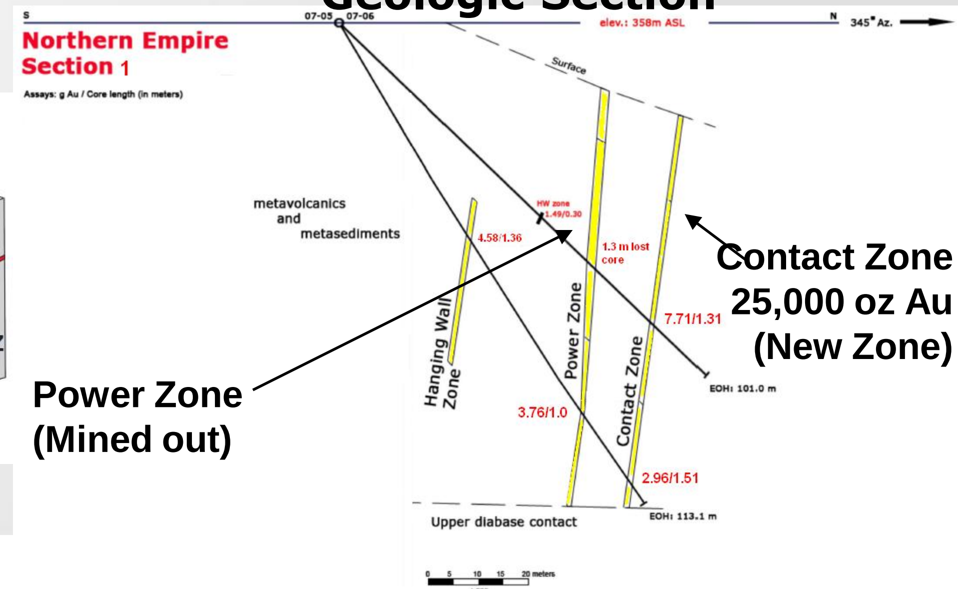
(Vein hosted Au associated with py-po sulphides)

Northern Empire Mine (1934-1941)
149,053 ounces of gold produced

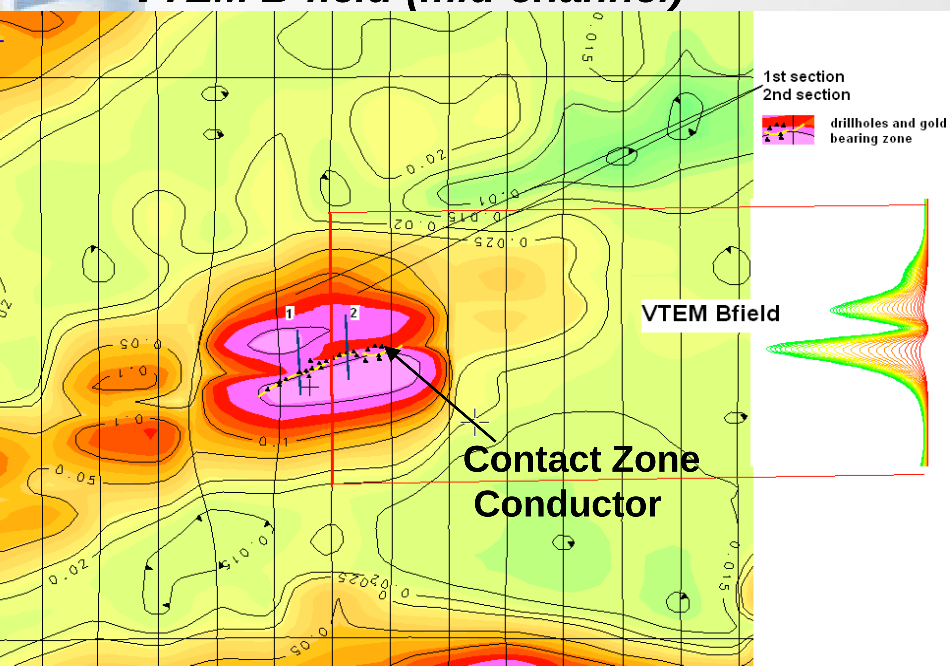


From Dubé, and Gosselin, 2007

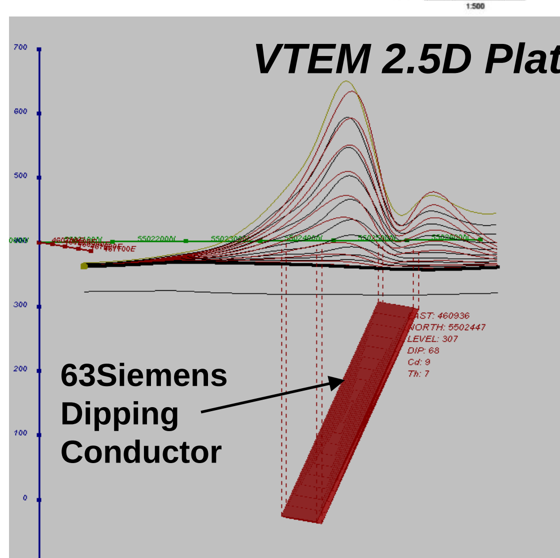
Geologic Section

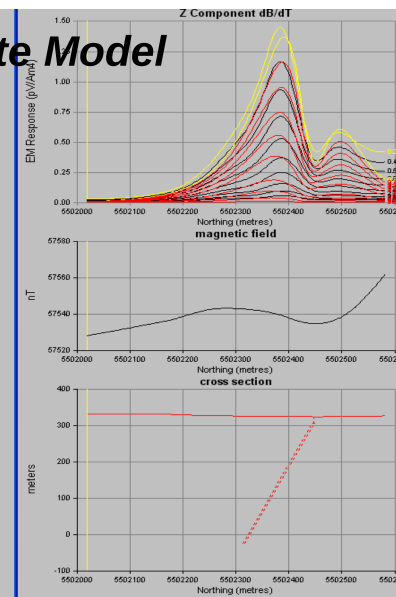


VTEM B-field (mid-channel)



VTEM 2.5D Plate Model



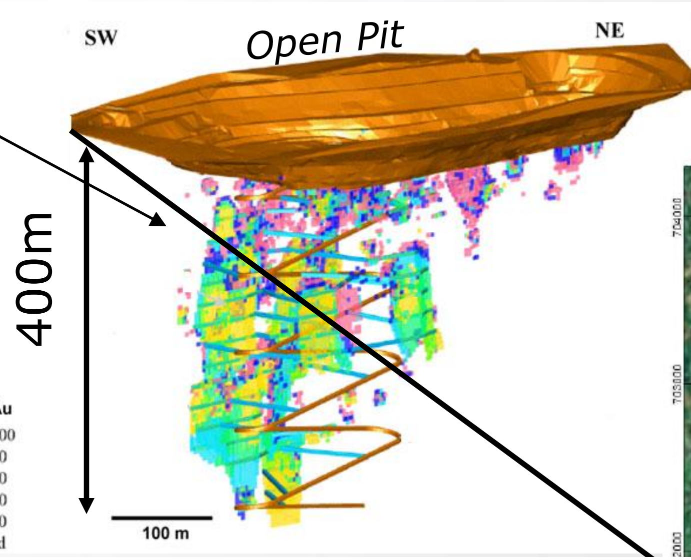


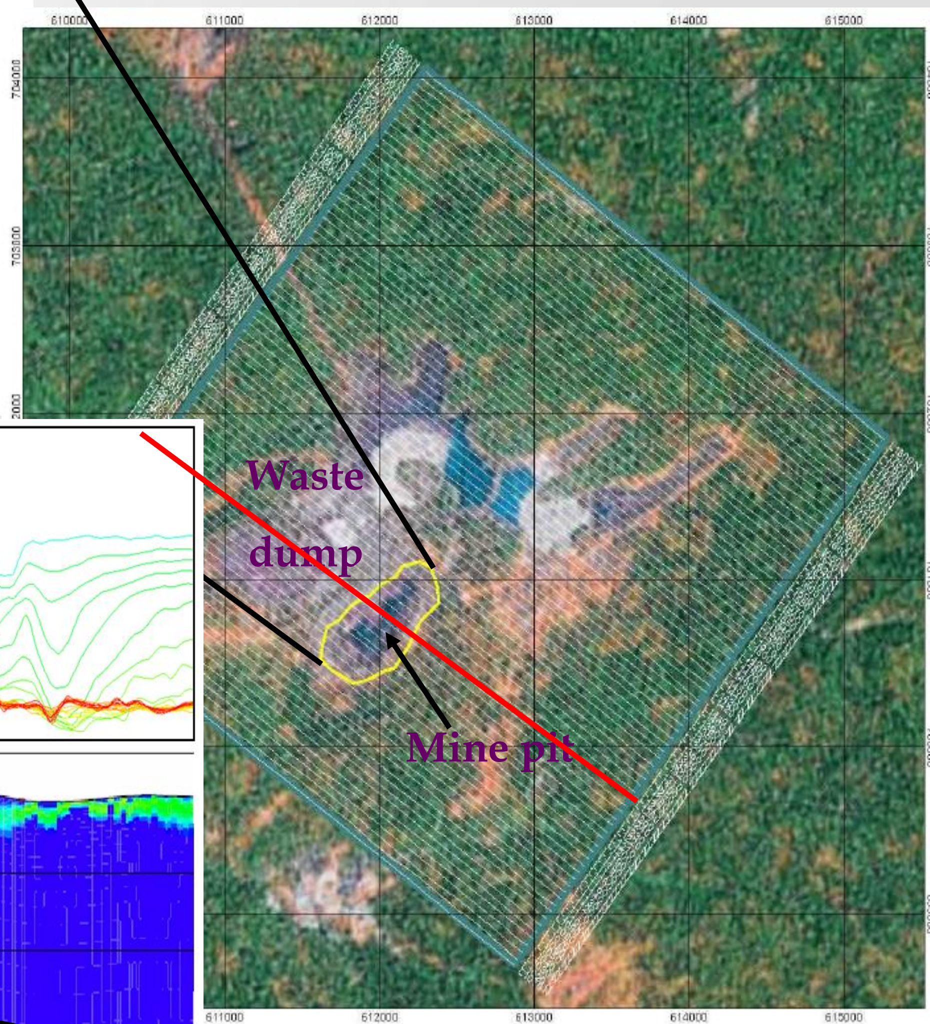
(courtesy Kodiak Exploration Ltd., 2010)

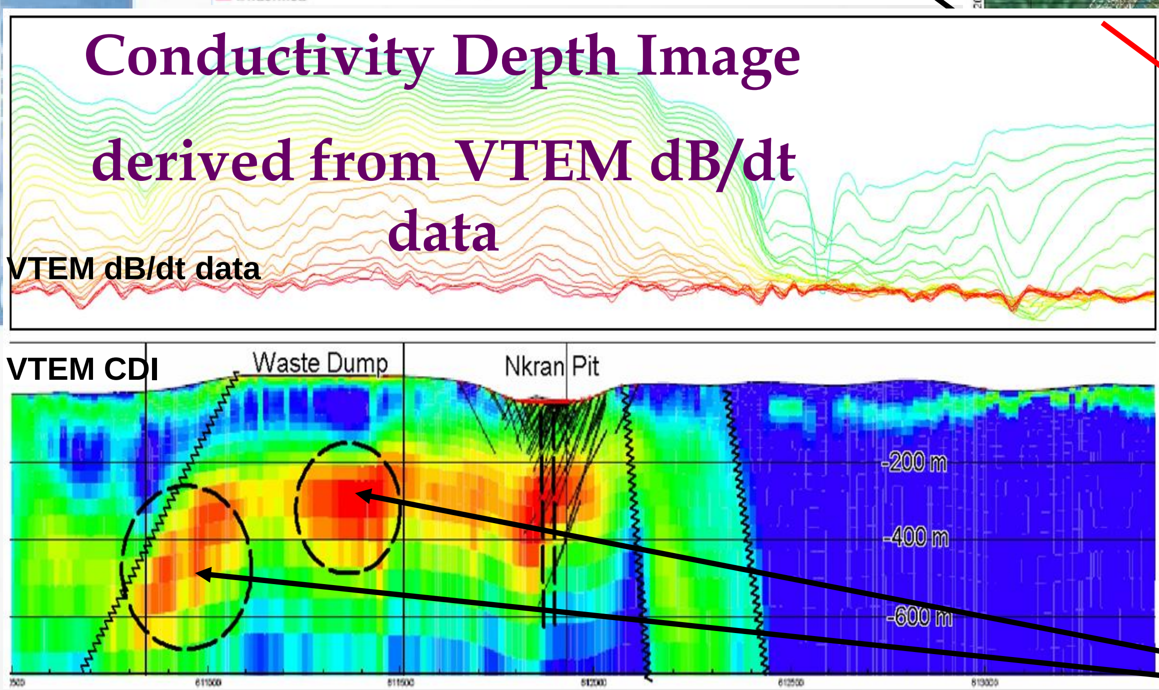
VTEM for Gold: Nkran Mine, Ghana 2005

(Greenstone hosted Au associated with py-as sulphides)

1-2 million ounces Au grading above 3.0 g/t





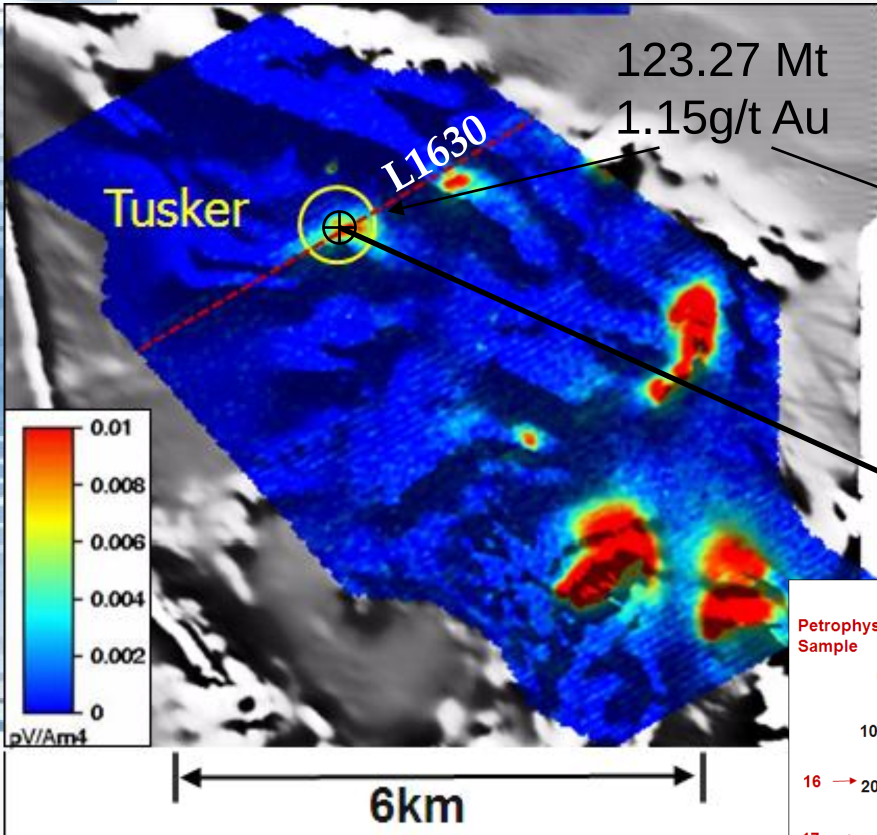


Potential new targets

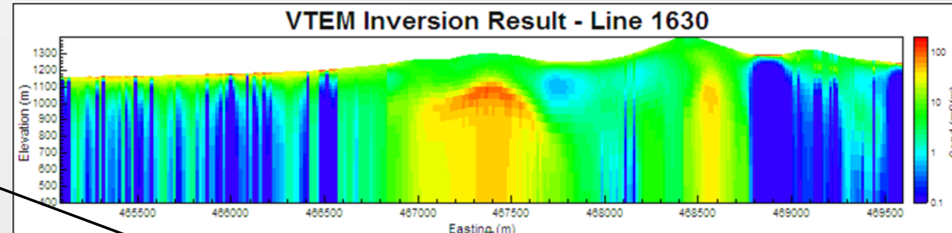
(Courtesy PMI Gold, 2008)

VTEM for Gold: Tusker Mine, Tanzania

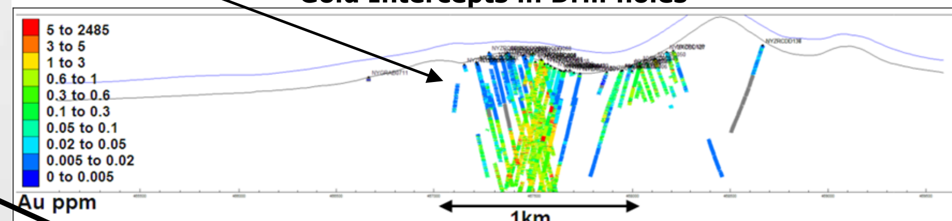
(Sediment-hosted Au associated with py-po sulphides)



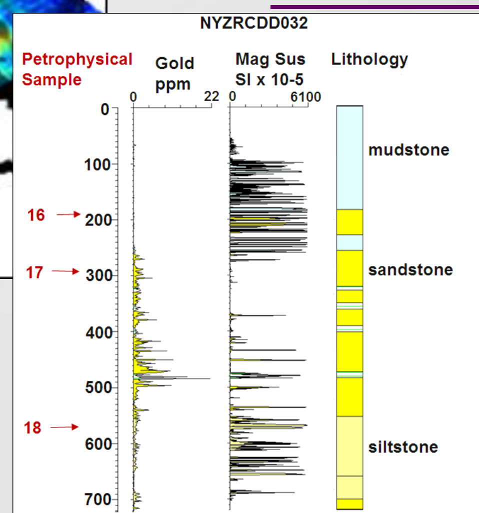
VTEM data over greyscale 1VD of RTP airborne magnetic data



Gold Intercepts in Drill holes



Drill hole NYZRCDD032



#	Drillhole NYZRCDD	Gold ppm	Depth m	Lithology	Mag Sus SIx10^{-5}	WBD g/cm^3	apparent EM cond. S/m	Galvanic Res. ohm m	IP ms
16	32	0.005	189.75	Sandstone	89 263	2.90	→ 0	68323	66
17	32	0.75	290.0	Sandstone	2229 1122	2.93	23 - 200	2.3	221
18	32	0.42	569.9	Sandstone	189 128	2.77	→ 0	60044	34
22	126	0.005	176.35	Sandstone	8 3	2.70	→ 0	11053 12770	8 13
23	126	0.005	164.6	Mudstone	18 14	2.77	→ 0		

(courtesy Barrick Gold, 2009)

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Part 4: VTEM – Versatile Time Domain electromagnetics and ZTEM – Z-axis Tipper (AFMAG) electromagnetics

Mineral Exploration Case Study Examples

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VTEM & ZTEM over Carbonate Replacement Deposits

Cinco de Mayo, Chihuahua MX

(Mo-Gold & Silver-Pb Discoveries)

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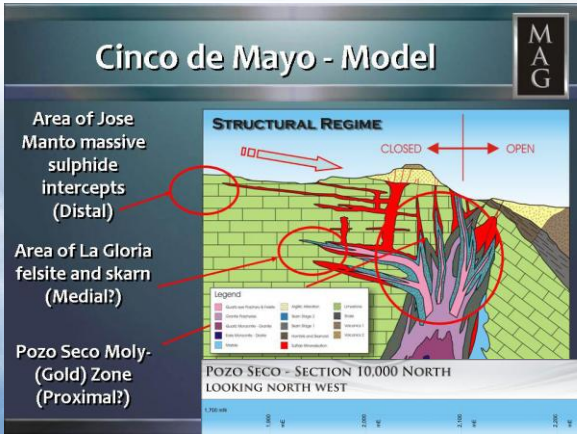
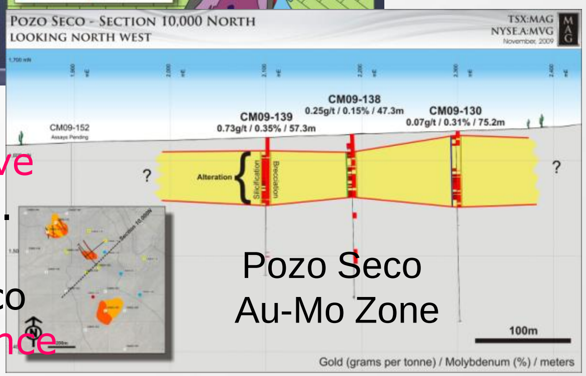
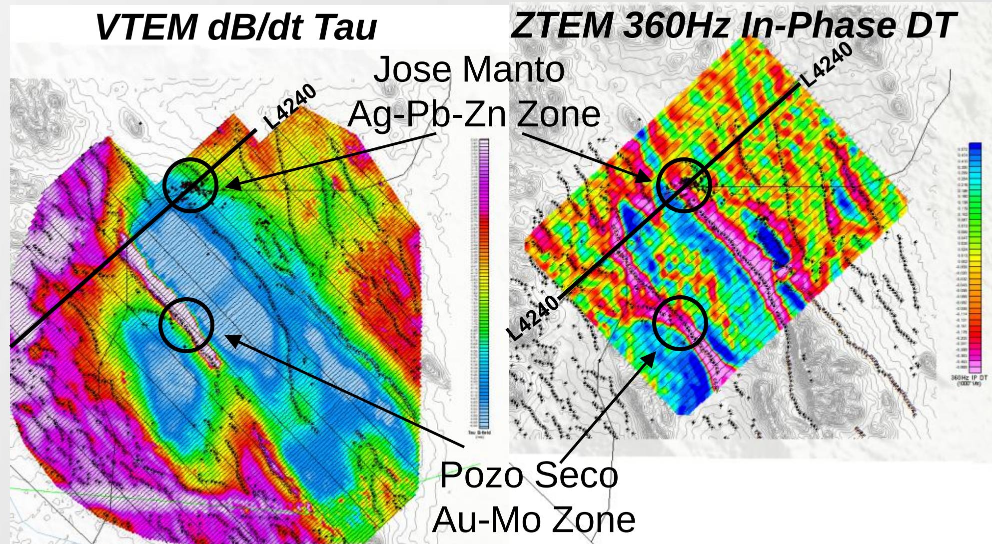
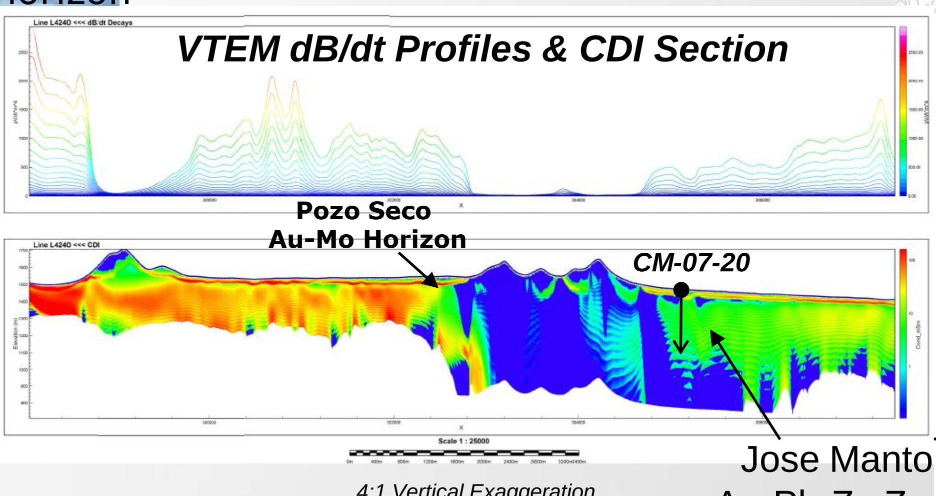
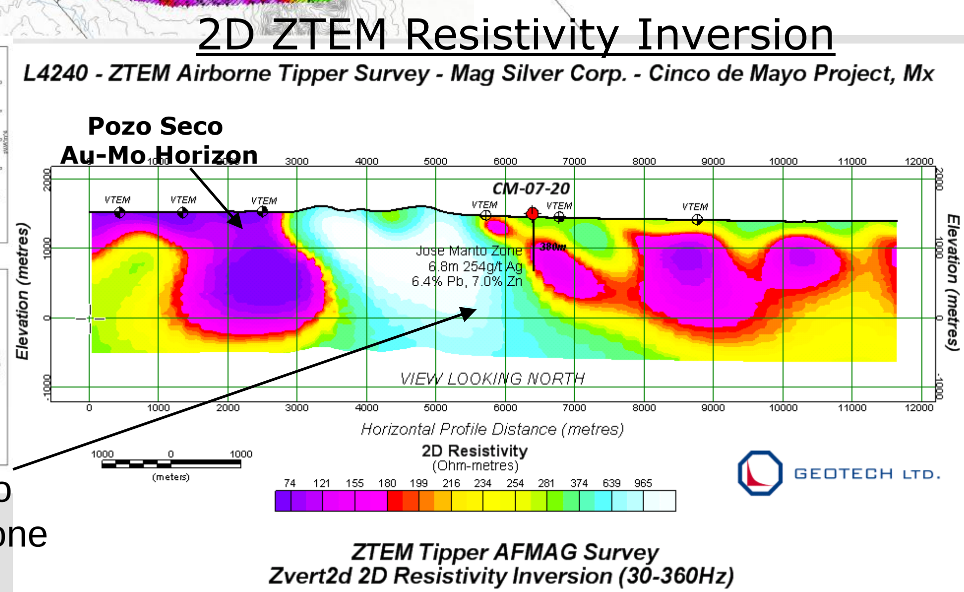




ZTEM maps weakly conductive Jose Manto zone. VTEM better defines Pozo Seco higher conductance horizon





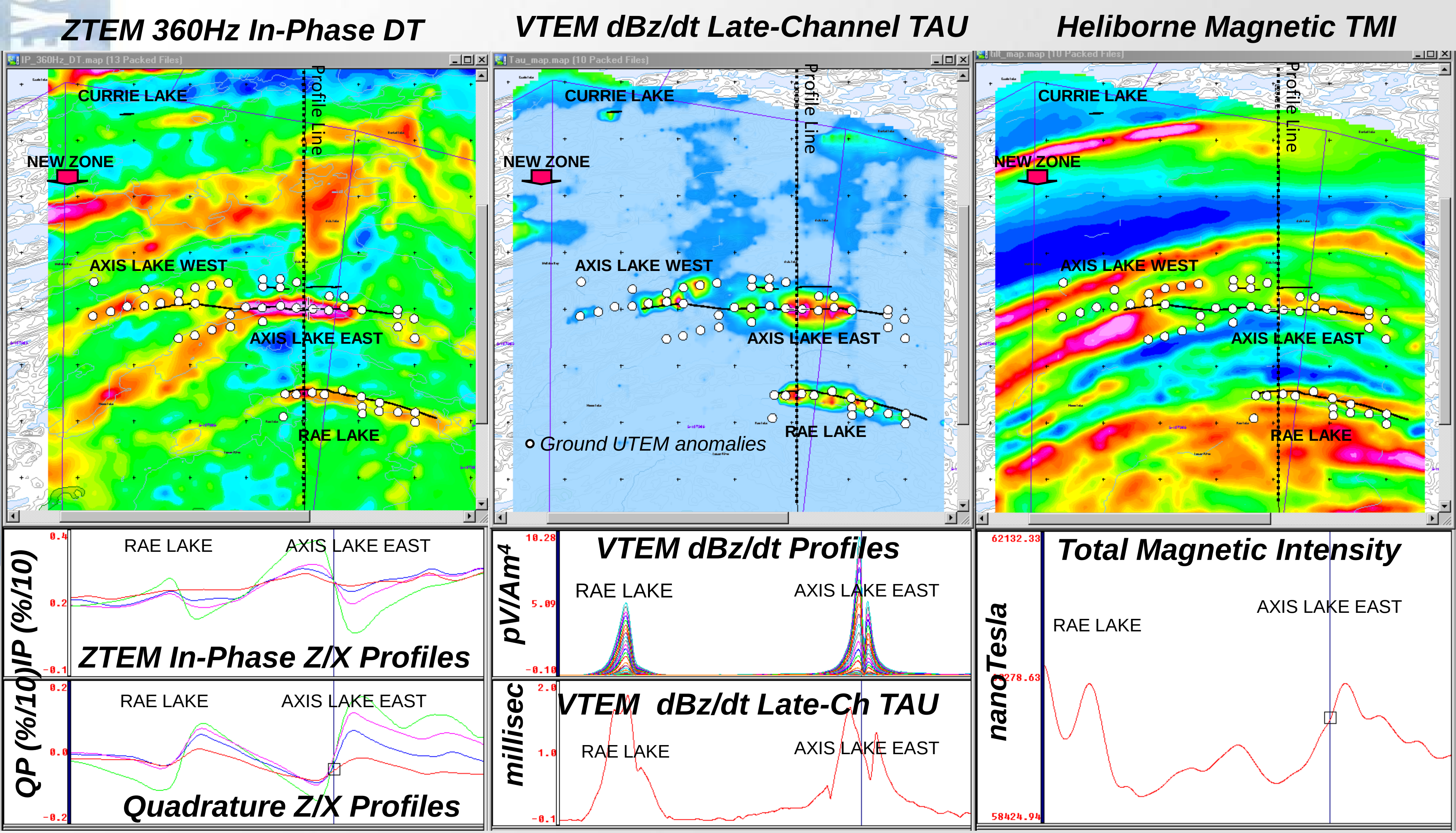


(courtesy Mag Silver Corp., 2010)

ZTEM-VTEM for MMS Magmatic Cu-Ni Massive Sulphides: Axis Lake, SK

(3.6 Mt @ 0.66%Ni, 0.6% Cu)

ZTEM provides a resistivity mapping capability, similar to magnetics, that augments the VTEM metal detection.



Showing ZTEM VTEM and Magnetic Results for Axis Lake Ni Deposit in N. Saskatchewan

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Part 5: ZTEM – Z-axis Tipper (AFMAG) electromagnetics

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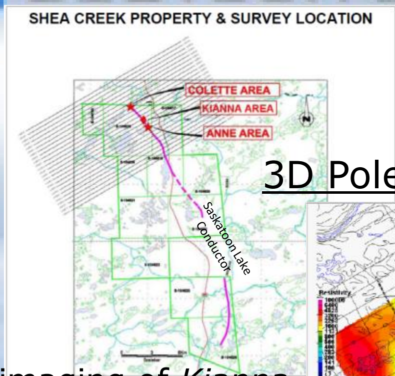
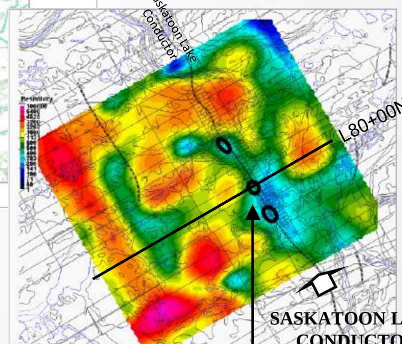
ZTEM for Unconformity Uranium, Shea Creek, NW Sask. Canada
(Below 700m Athabasca Sandstone)

Geotech Ltd. Airborne Geophysical Surveys



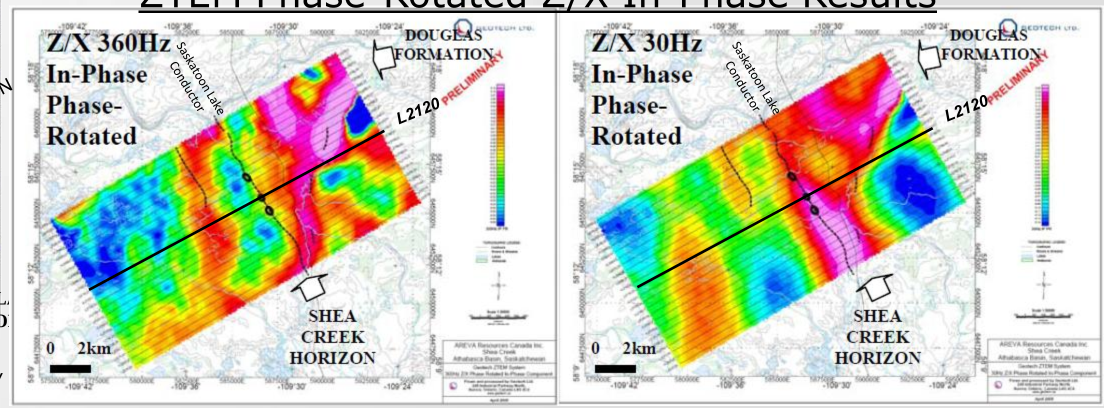
ZTEM imaging of *Kianna clay*-alteration zone and deeper Saskatoon Lake graphite conductor equivalent to ground methods at Fraction of Cost.

3D Pole-Pole DC Inversion



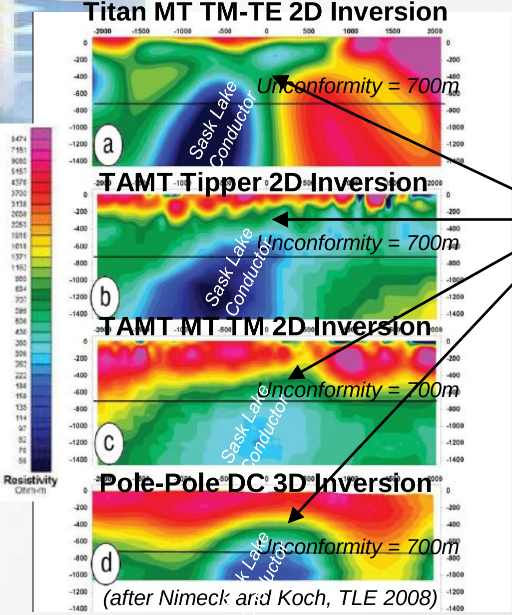
(modified after Bingham et al., 2006)
Note Reverse colour scale (Blue=Low Resistivity) relative to other Slides

ZTEM Phase-Rotated Z/X In-Phase Results



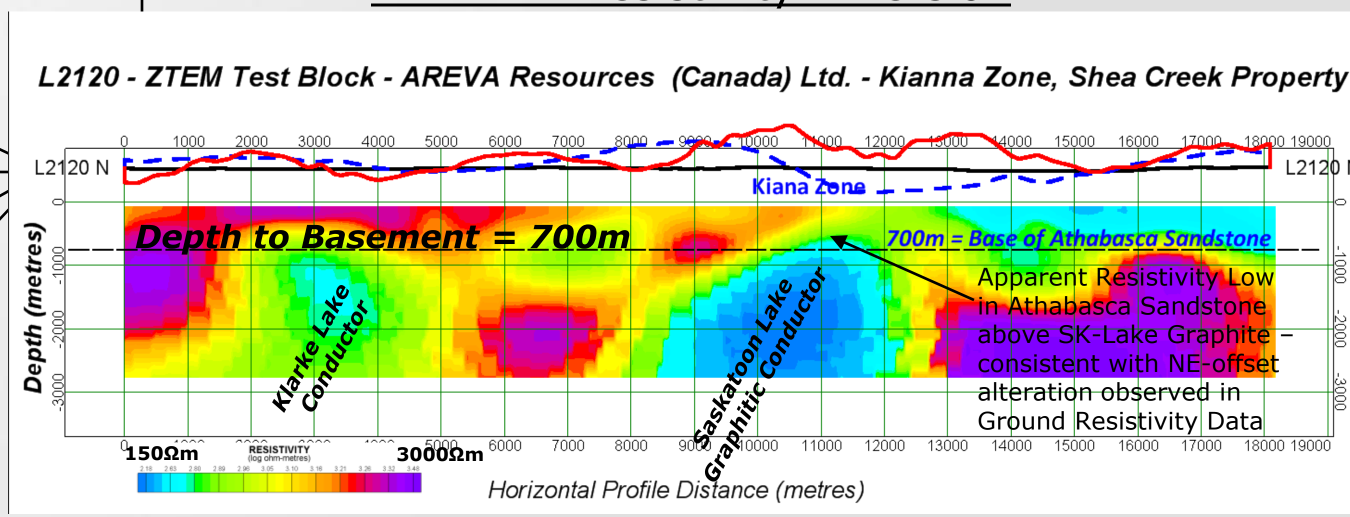
Shallower Penetration **Deeper Penetration**

Shea Creek L80N Ground Results



(after Nimeck and Koch, TLE 2008)
Note: Reverse colour scale (Blue=Low)

2D ZTEM Resistivity Inversion



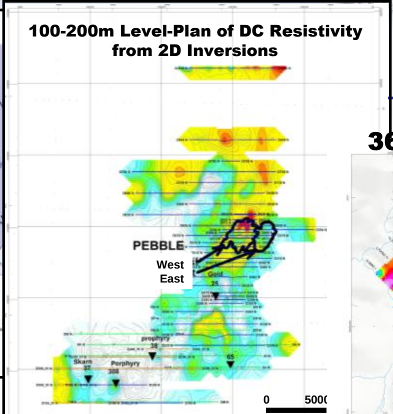
(Courtesy AREVA Resources (Canada) and UEX Corporation (2009))

Showing ZTEM Results over Kianna Zone, at Shea Creek NW Saskatchewan Canada

ZTEM for Porphyry Copper Deposits:

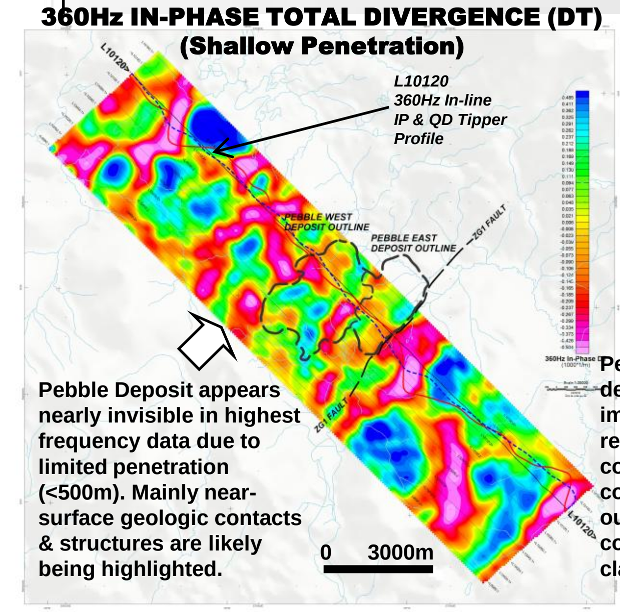
Pebble Cu-Gold, Alaska USA

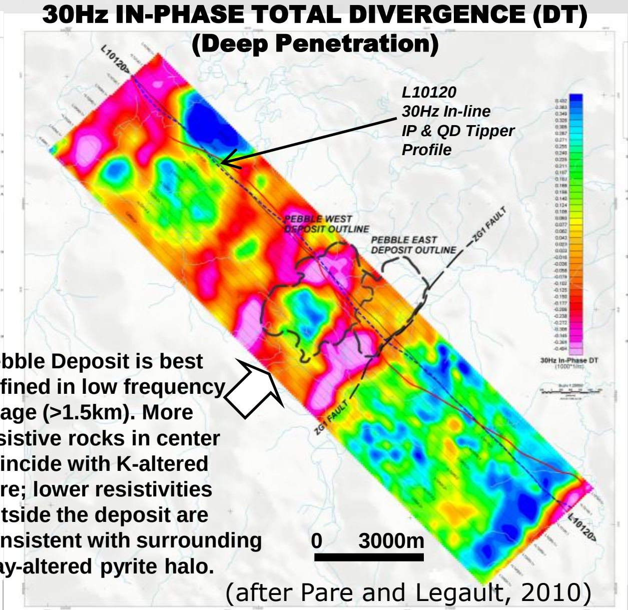
(1st Largest Gold and 4TH Largest Copper Deposit)



(courtesy Anglo-American, 20

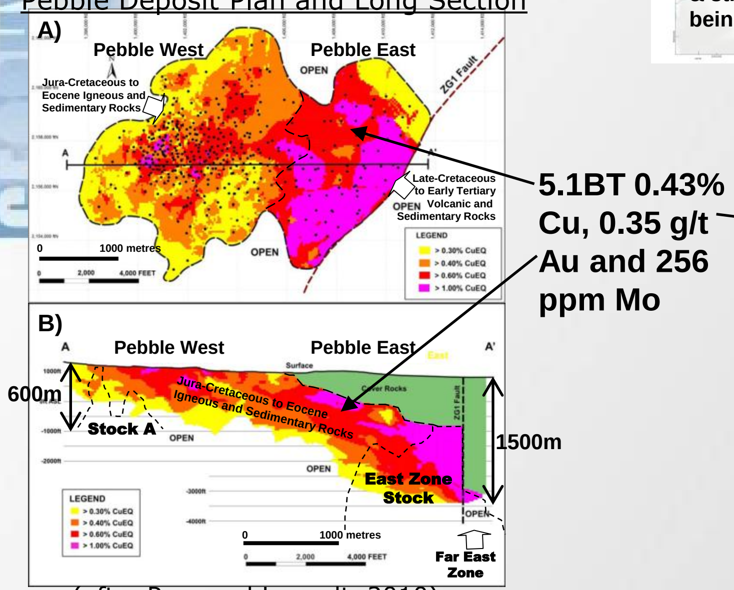
ZTEM is the ONLY Airborne technique designed and proven to map *Porphyry* deposits to great depth.





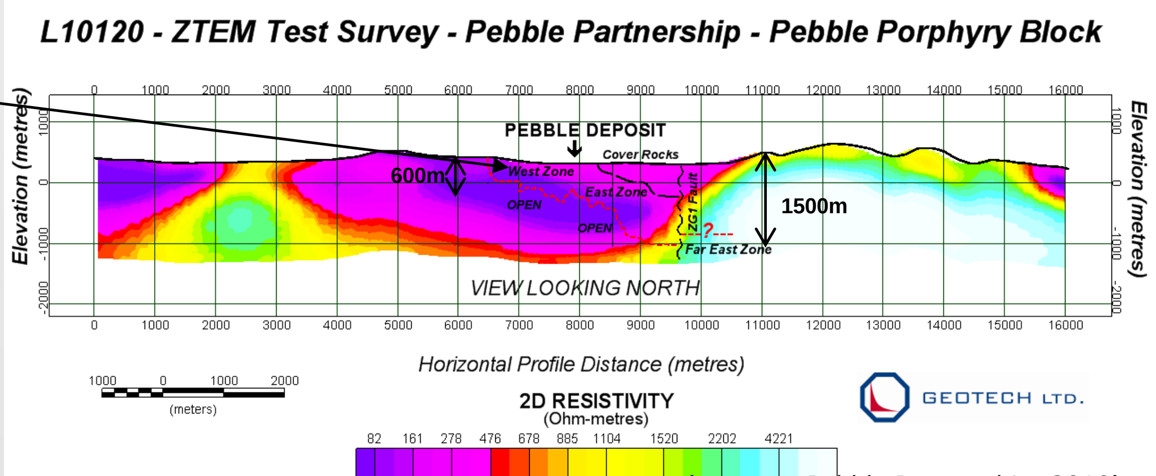
(after Pare and Legault, 2010)

Pebble Deposit Plan and Long Section



(after Pare and Legault, 2010)

2D ZTEM Resistivity Inversion



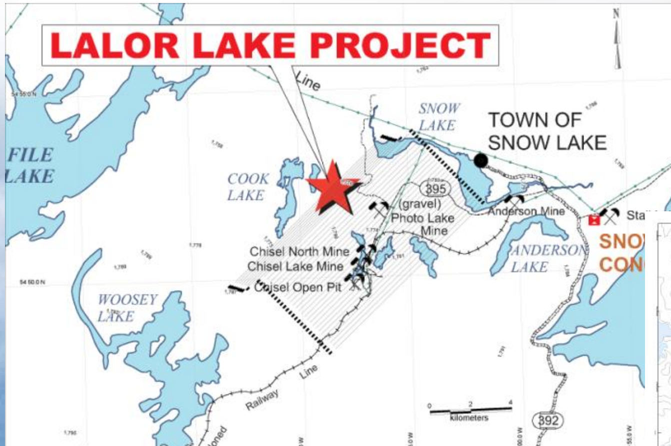
(courtesy Pebble Partnership, 2010)

Showing ZTEM Results for Structural & Lithologic Mapping over a known Porphyry

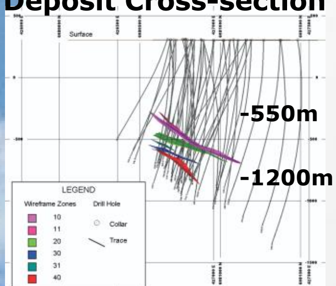
ZTEM for Volcanogenic VMS Massive Sulphides:

Lalor Lake Cu-Gold, Manitoba CA

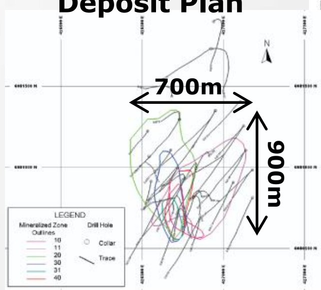
(12.3 MT buried at >550-1200m Depth)



Deposit Cross-section



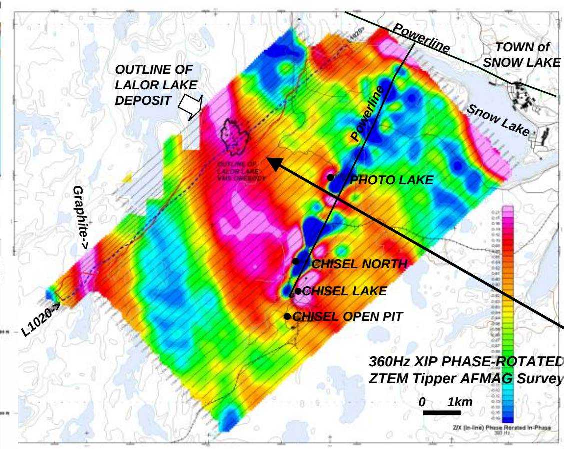
Deposit Plan



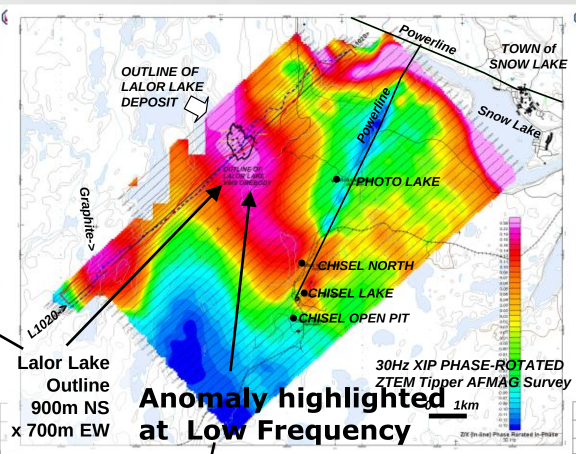
Lalor Lake Deposit drill holes and mineralized zone outlines in a) Long section (left) & b) Plan (right) – Courtesy Hudson Bay Minerals (2010).

ZTEM is the ONLY Airborne technique that has detected the Lalor Lake VMS deposit (12.3MT 1.6 g/t Au, 24.2 g/t Ag, 0.66% Cu, 8.70% Zn)

ZTEM Phase-Rotated Z/X In-Phase Results

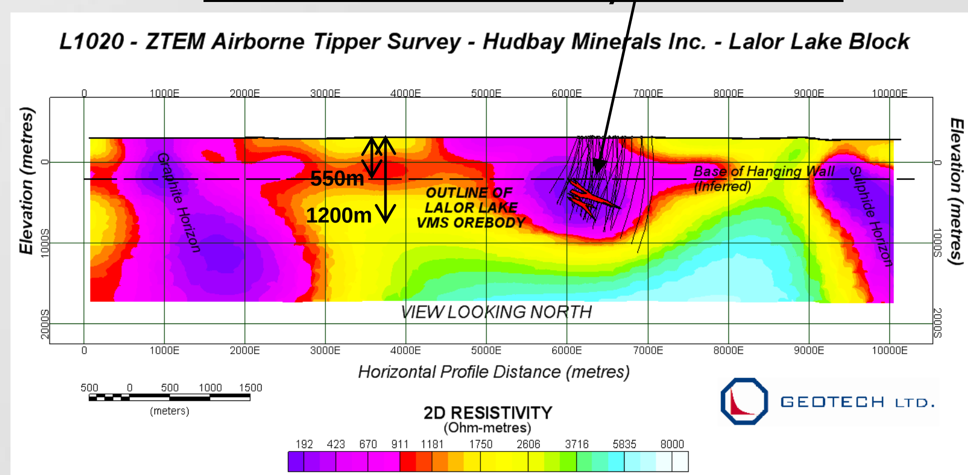


Lalor Lake Outline 900m NS x 700m EW



Anomaly highlighted at Low Frequency

2D ZTEM Resistivity Inversion



(courtesy Hudbay Minerals Corp, 2010)

Showing ZTEM Results over Lalor Lake VMS Deposit, Snow Lake, Manitoba Canada

Conclusions – VTEM

- VTEM is an award winning and industry leading technology that is widely recognized as the finest helicopter EM platform in the world. More than 1,500,000 line-km have been flown since 2002.
- Its strengths lie in its:
  - A) Large transmitter dipole-moment (450,000 to 1,000,000 Am^2) – a combination of large diameter (26m to 35m=largest) and high current (200-300A), which provides a strong primary field, enabling deep penetration.
  - B) Long On-time (4.6msec to 7msec) pulse for more effective field saturation.
  - C) Long Off-time decay measurements (5 µsec to 12 msec) from low base-frequency (25/30Hz), which provides sampling to maximum diffusion depth.
  - D) Extremely low system noise (0.0009 to 0.0003 pV/Am^4) that contributes most greatly to anomaly resolution and penetration.
  - E) Superior “repair or replace” time, due to its modular design, avoids lengthy, costly delays.
  - F) High spatial sampling (0.1s = 2-3m stations) with accurate GPS positioning, give VTEM a “fly-to-drill” capability – reduced need for further geophysics ground follow-up.

Conclusions – ZTEM

- ZTEM is the only commercial AFMAG EM system of its type in the world, airborne and ground. More than 100,000 line-km flown in >70 projects, on 4 continents around the world.
- Its strengths lie in its:
  - A) Large (7.2m) single-axis receiver coil and fixed base-station reference coils (3.5m) that contribute to improved signal to noise over conventional AFMAG configuration.
  - B) Advanced digital signal processing of time-series that produces accurate/repeatable estimates of Tipper transfer functions, via FFT's, using established MT derivations (Labson et al.,1985).
  - C) Choice of 30-360Hz (+/- 720Hz) bandwidth that provides for stable primary field signal source, near-4 season surveying, and a deep penetration capability that extends beyond 250-500m range of inductive airborne EM methods.
  - D) Method's sensitivity to relative resistivity contrasts (i.e., maps both conductors & resistors) and, due to nature of plane-wave MT fields, its ability to be easily modeled in 2D-3D make it an ideal geologic resistivity mapping tool.

GEOTECH LTD. AIRBORNE GEOPHYSICAL SURVEYS

Thank You!

Xstrata Zinc
Spider Resources
Kodiak Exploration
Barrick Gold
Mag Silver
Anglo-American

KWG Resources
Noront Resources
PMI Gold
Condor Consulting
Pebble Partnership
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Ouro Preto, BR
May 2010