Exploring for copper-gold deposits with time-domain electromagnetics in the Chapais-Chibougamau mining camp: case history of a challenging variable environment.

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Summary

Following petrophysical studies, geological and geophysical data compilation, the former Opemiska underground mine of the Chibougamau District was selected for conducting an experimental TDEM surface ground survey. Fourteen different sites confirmed the variability of the EM response associated with chalcopyrite veins, and the difficulty in relying on an equivocal signature to locate the massive sulfides. Petrophysical measurements and microscopic observations suggest complex interrelations between the amount of ore in the rock, fabric, texture, porosity, mineralogy and impurities, leading to a wide range of bulk conductivity values that suggest chalcopyrite might be a semiconductor at this site.

Background

The Opemiska mine, located besides the town of Chapais, Québec, produced copper, silver and gold from 1953 to 1991. Part of the Abitibi greenstone belt (fig.1), the former Opemiska underground mine used shafts and galleries to extract narrow but high-grade syn-magmatic copper-gold veins formed through hydrothermal processes (Salmon, 1982).

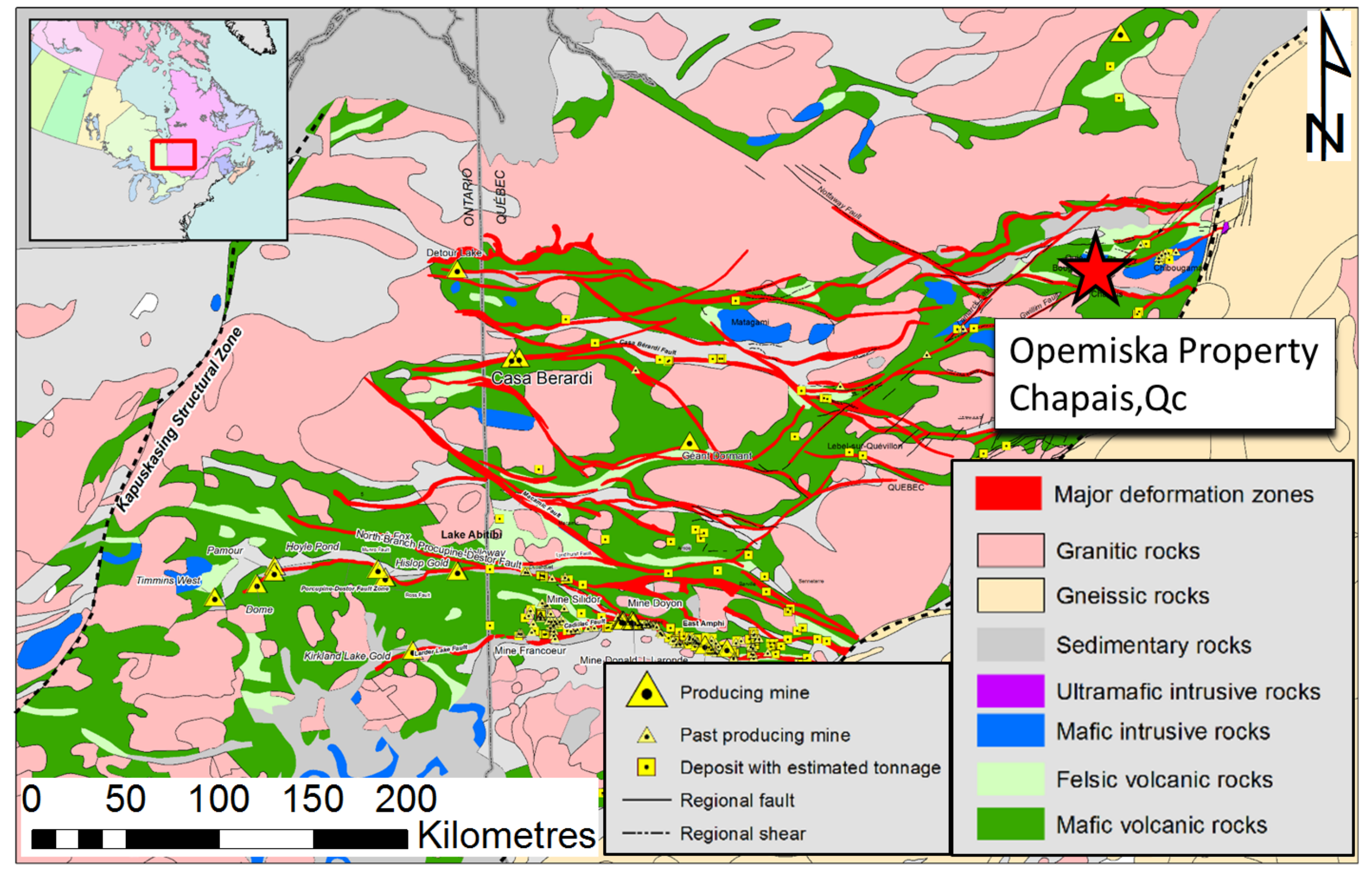

Figure 1. Location of TDEM experiments (modified from Parsons et al., 2015).

Problem

The exploration problem consists in finding new ore zones close to the surface that can be mined economically. Even though the ore consists of semi-massive to massive chalcopyrite-gold veins with quartz-carbonate ± pyrite-pyrrhotite-magnetite, geophysical work such as resistivity/IP, magnetic and MaxMin surveys on the property didn't provide a direct vector to the mineralization itself.

Objective

The TDEM survey aimed to understand the response characteristics in the different areas so we could develop a procedure to explore and map near-surface copper-gold ore, both low-grade zones and rich massive veins, with varying strike, dip, plunge and length.

Methodology

Fourteen different sites were investigated with an impulse-response TEM system to evaluate different environments with varying conductivity, chargeability, magnetic response, sulfide content, rock type and texture. The configuration of the 2015 transient EM investigation consisted of:

- A square fixed-loop transmitter of 50m side length (fig.3a);
- Survey lines radiating from its center at 45 degrees;
- Receiver stations spaced every 5m;
- A squared waveform powered by a 20A-50V transmitter;
- A base frequency ranging from 3 to 30 Hz;
- A Geonics three-component dB/dt coil sensor (200 m^2, 29 kHz);
- A GDD NordicEM digital 24-bit EM receiver (120,000 Hz).

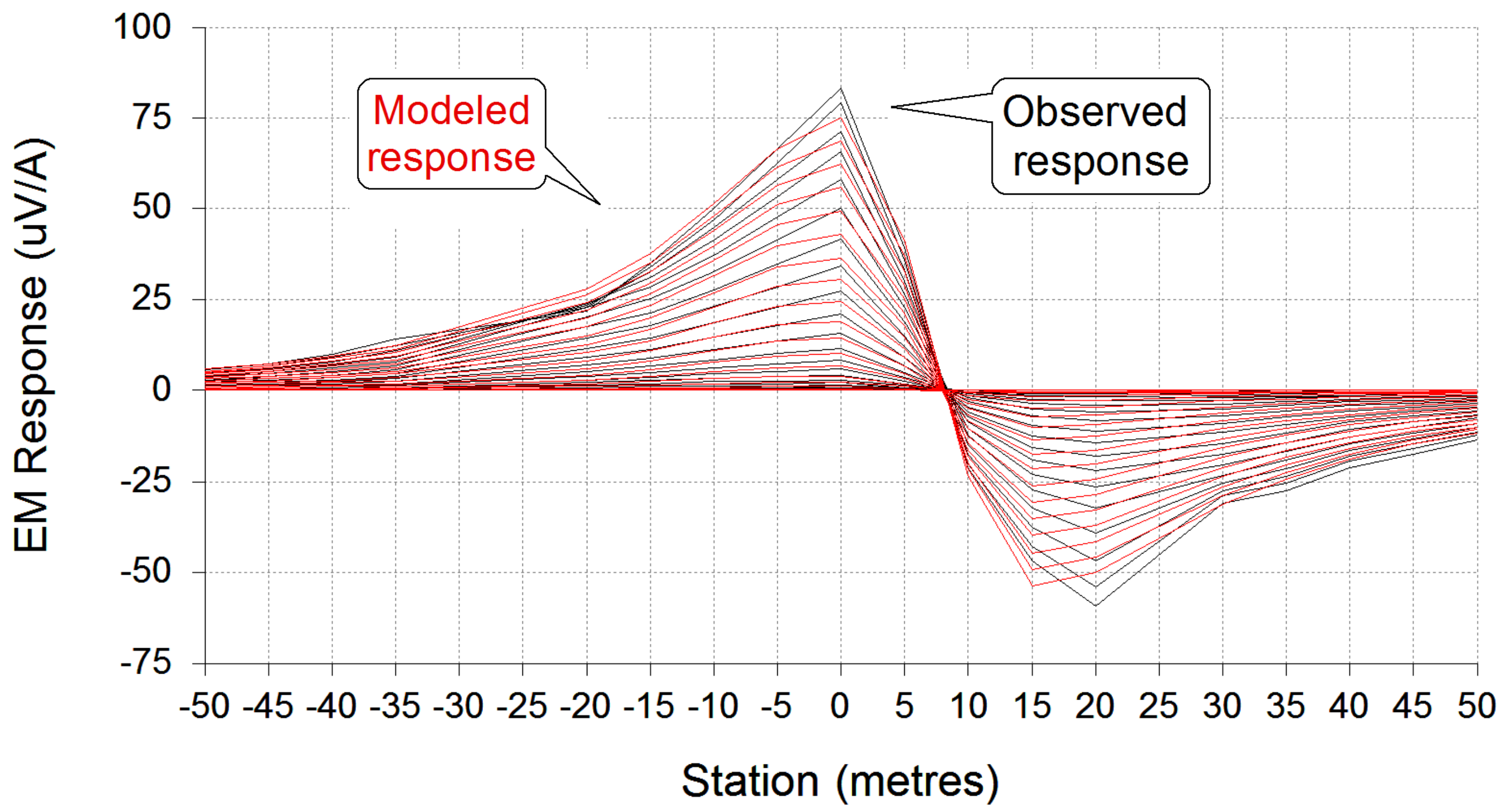

Fig. 2. Site #2. Profile of Z component for L0, at 15 Hz, with channels 0.08 to 16.484 msec The observed response is illustrated in black, and the modeled response in red.

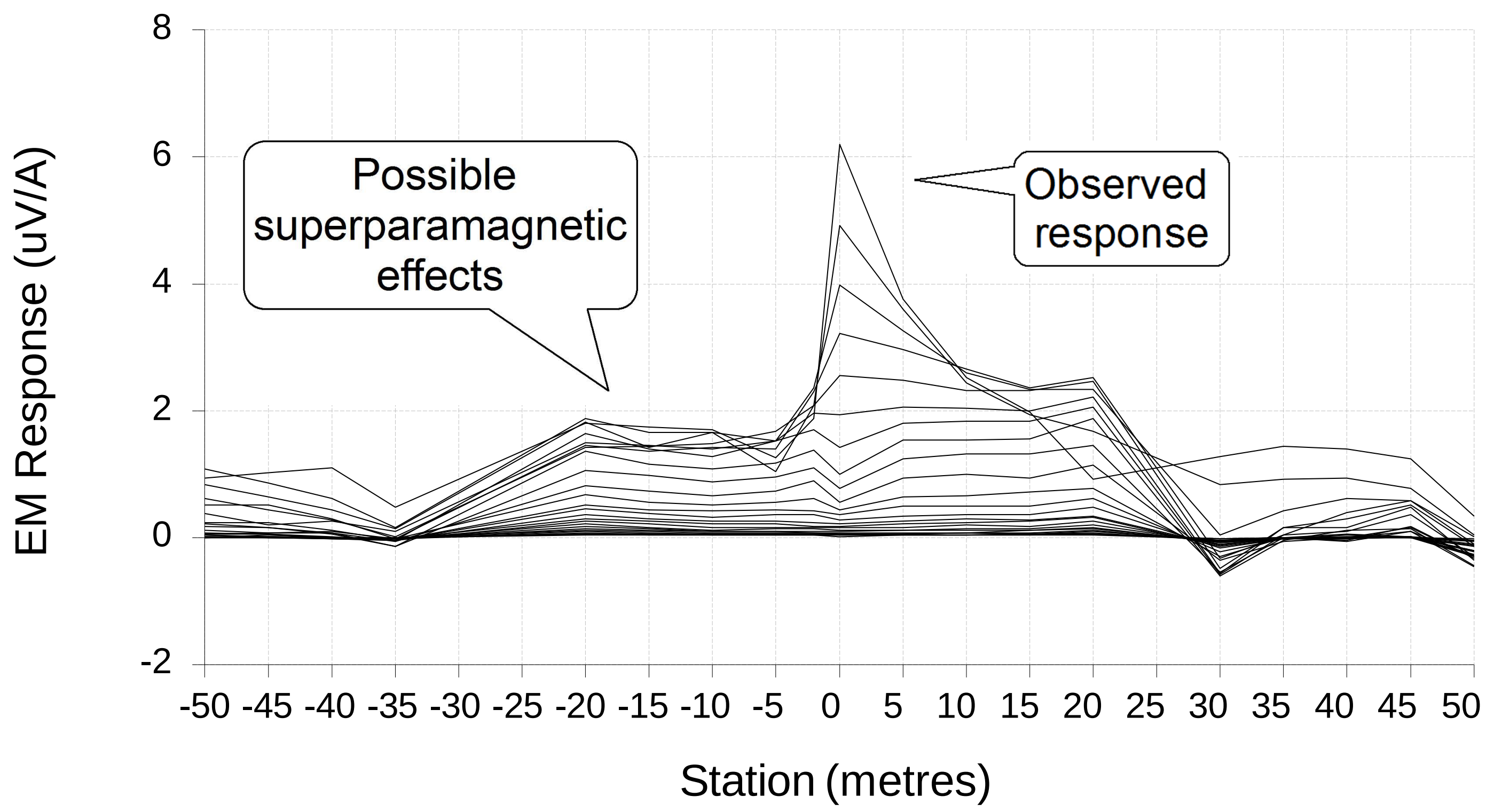

Fig. 4. Site #4. Profile of Z component for L0, at 30 Hz, with channels 0.08 to 7.95 msec. The conductive anomaly of the vein is only visible on windows 1 to 5, between -5 and 5m.

Results from the TDEM survey

Figure 2 illustrates the conductive response (in black), and the modeled response (in red), from site #2, with a 100 m NS line profile (L0), perpendicular to the sub-vertical vein target. The conductor corresponds to a known horizon of pyrrhotite and chalcopyrite. The EW trend of the conductor was defined by modelling all lines in 3D with a plate in free space (red body in fig.3a). Interpolating in 2D the secondary magnetic field from TDEM window 1 data (fig.3b) exhibited the same location and trend direction (277°) as the red body modelled in 3D. Another site surveyed (site #4), with a NS line (L0) perpendicular to a massive chalcopyrite-pyrite vein (fig. 5) shows a weak EM response decaying rapidly (fig.4). The amplitude of the anomaly is reduced by a factor of about 10 in comparison with site #2.

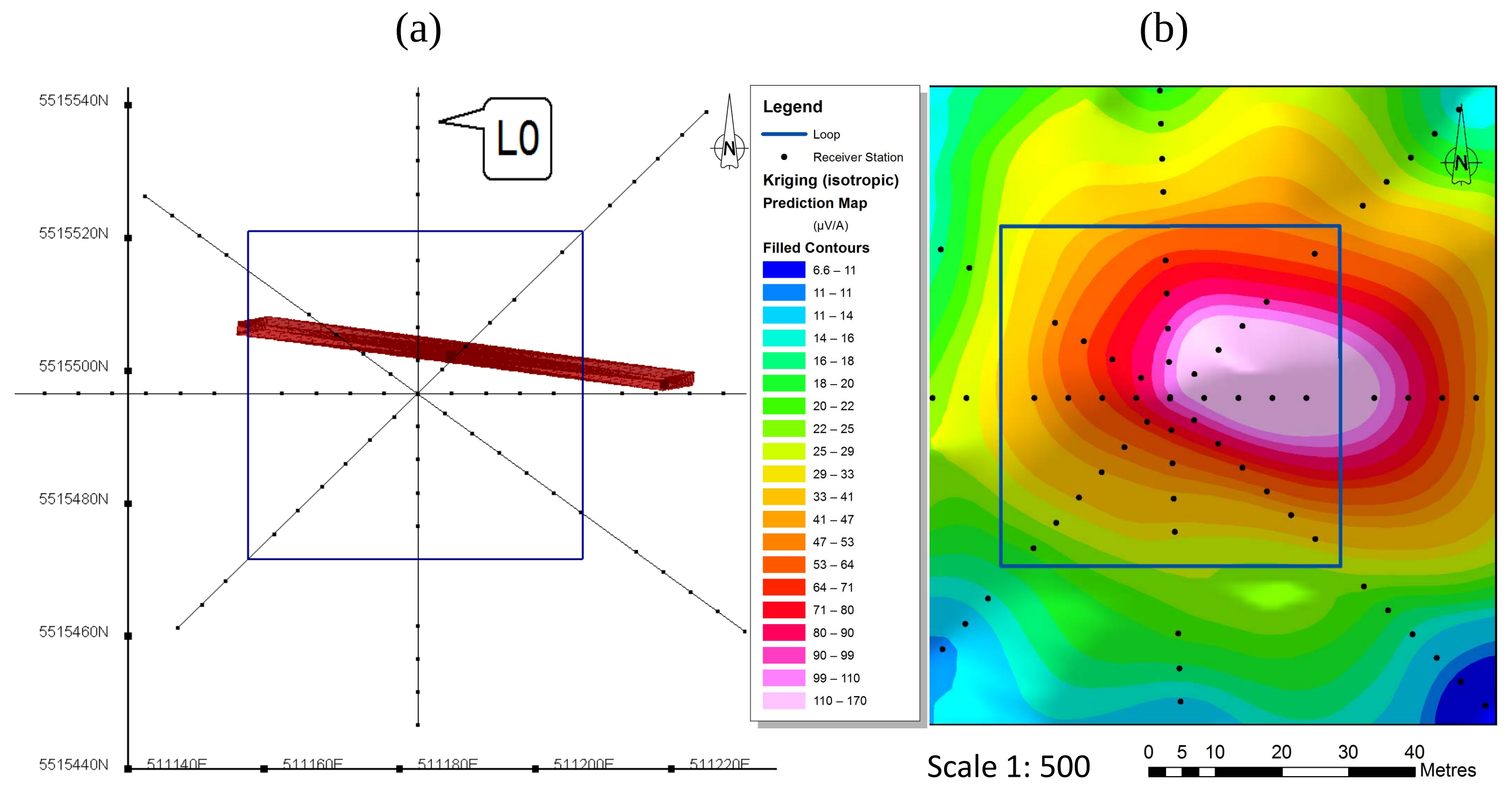

Fig. 3. Site #2 (a) Plan view of the 50 x 50m square-loop layout with surveyed lines. The surface projection conductive plate model is also shown in red. (b) Kriging of the observed secondary magnetic field (SMF) for the 3 components X, Y and Z, from the first TDEM window (0.08 to 0.09 msec). SMF $= \sqrt{x^2 + y^2 + z^2}$

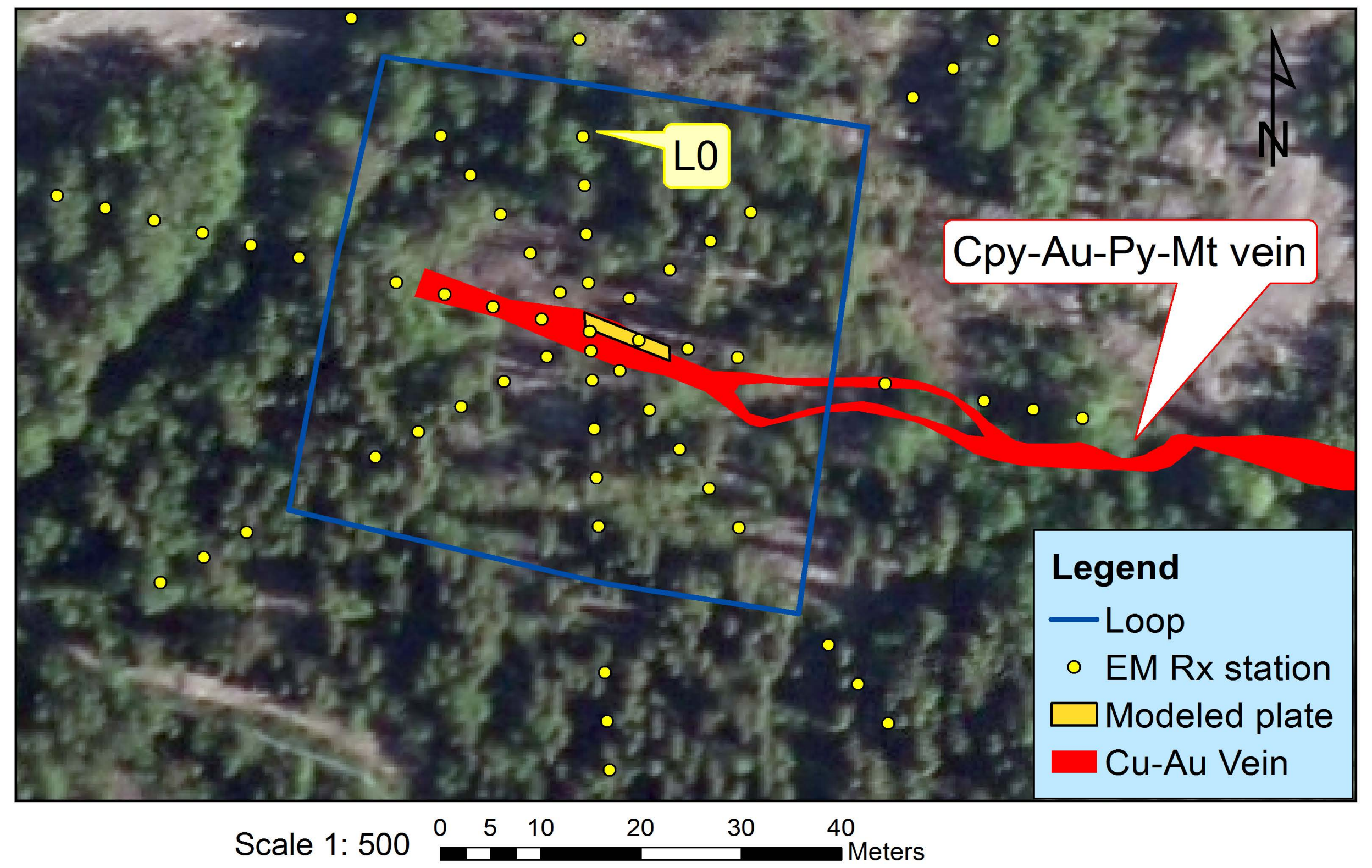

Fig. 5. Site #4. Plan view of the 50 x 50m square-loop layout with surveyed stations (yellow dots). The surface projection of the vein is shown in red, with the plate model shown in yellow near the center of the loop.

Petrophysical and microscopic observations

Measurements on core samples with MPP and SCIP hand-held instruments allowed us to establish a conductivity range for different chalcopyrite veins (fig. 6 and 7). From these observations, we concluded there is not a direct relationship between conductivity and copper grades. Microscopic observations on polished thin sections lead to the interpretation that high conductivity could also be caused by pyrrhotite (fig.8), while chalcopyrite rich sulfides had a relatively weaker conductivity caused by resistive silicates or molecular film of impurities surrounding and insulating the grains from each other (fig.9).

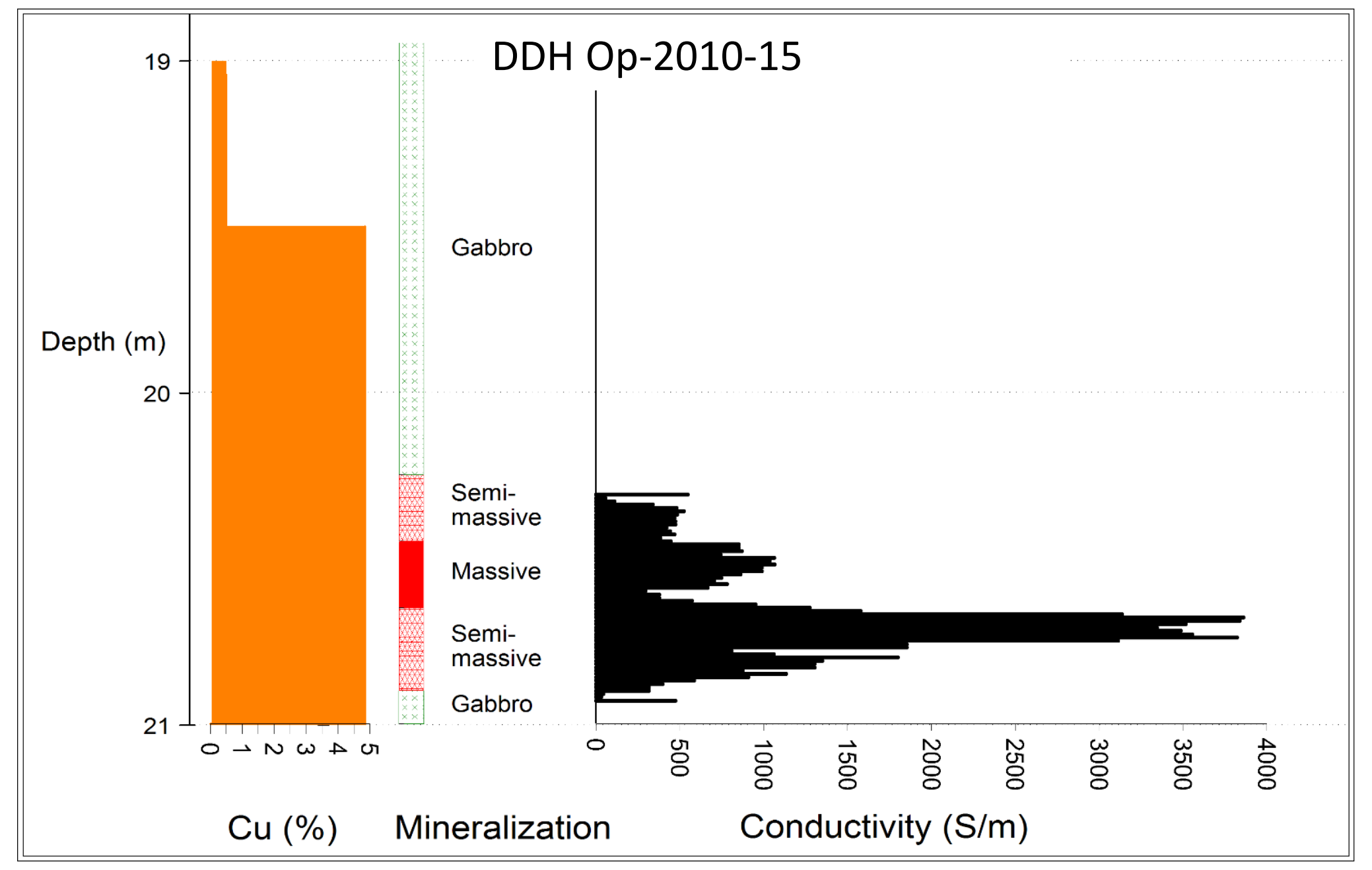

Fig. 6. Petrophysical measurements on core samples with MPP hand-held instrument. High conductivities of 500-4000 S/m were obtained from samples with copper grades with up to 4.8% Cu.

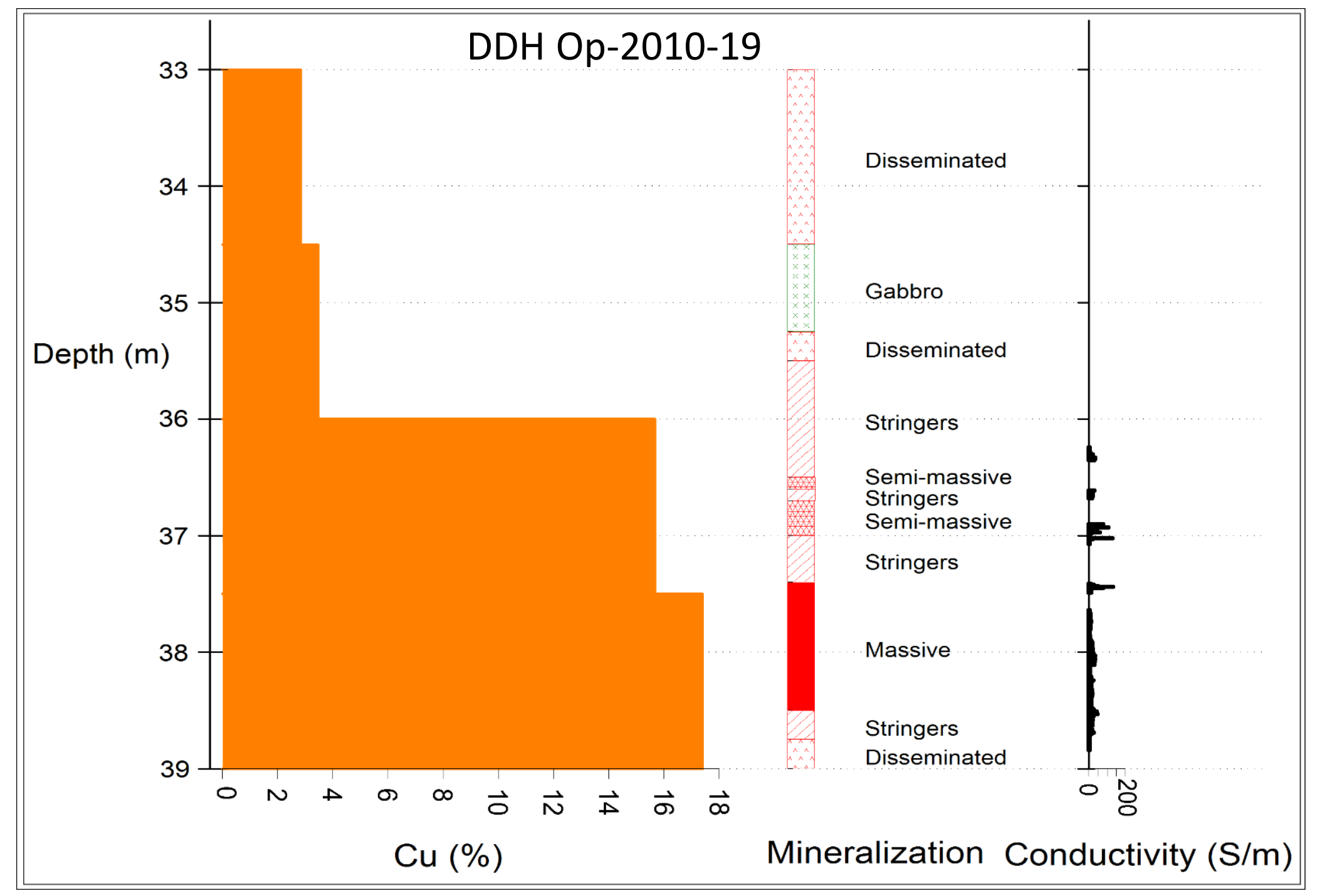

Fig. 7. Petrophysical measurements on core samples with MPP hand-held instrument. Low conductivities of 10-100 S/m were obtained from samples with copper grades with up to 17.4% Cu.

Conclusion

The TDEM survey conducted on the Opemiska property demonstrated considerable conductivity variability, with high copper grades not guaranteeing a strong response. Our thin section work implies that the lower conductivities are due to the conductive grains being surrounded by resistive material and not electrically connected. From an exploration perspective, prospecting for massive and disseminated chalcopyrite in the area should also be targeting weak conductive anomalies or some other physical properties (SPM), since the Cu-Au ore did not always show a direct correlation with high bulk conductivity.

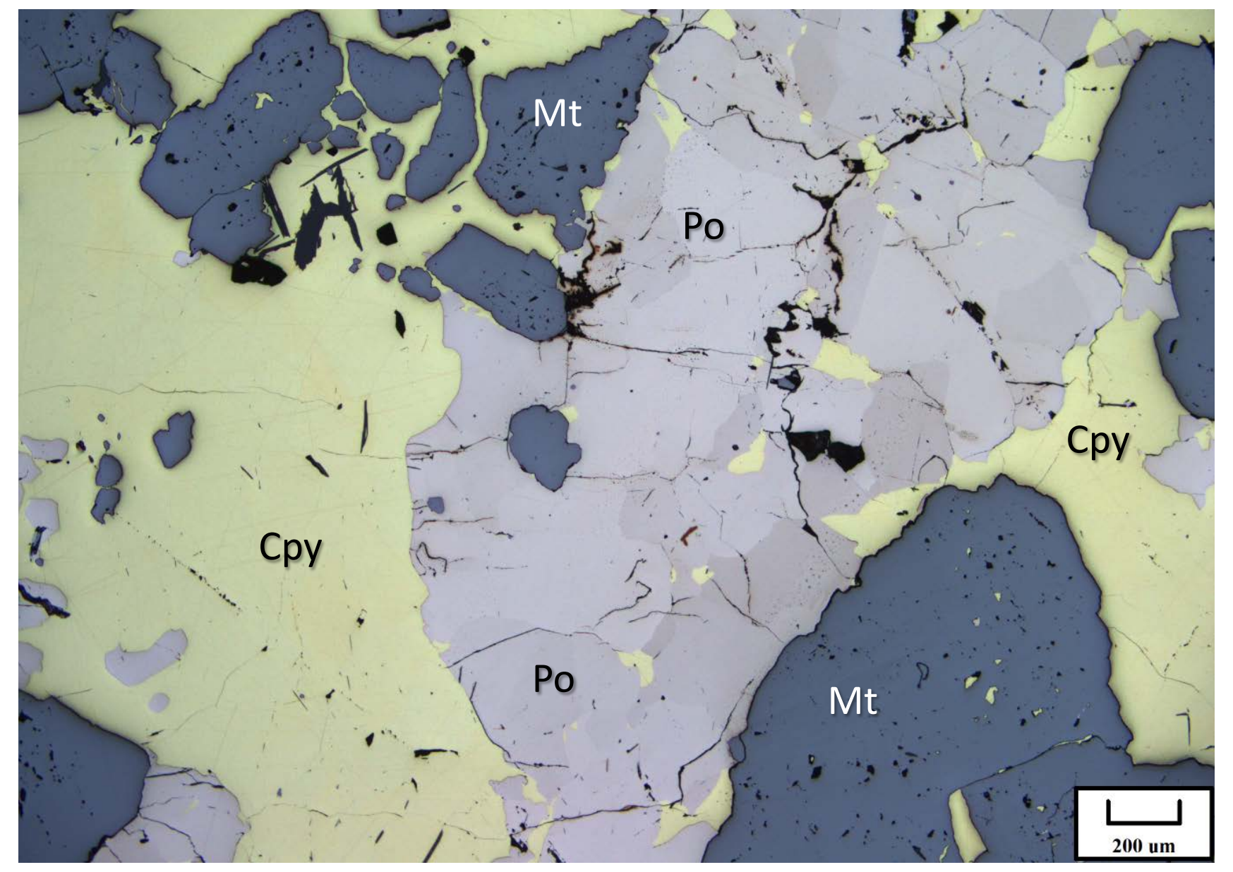

Fig. 8. Microscopic observation from a polished thin section from the highly conductive site presented at fig.6. Pyrrhotite (Po) intercalated with chalcopyrite (Cpy) and grains of magnetite (Mt).

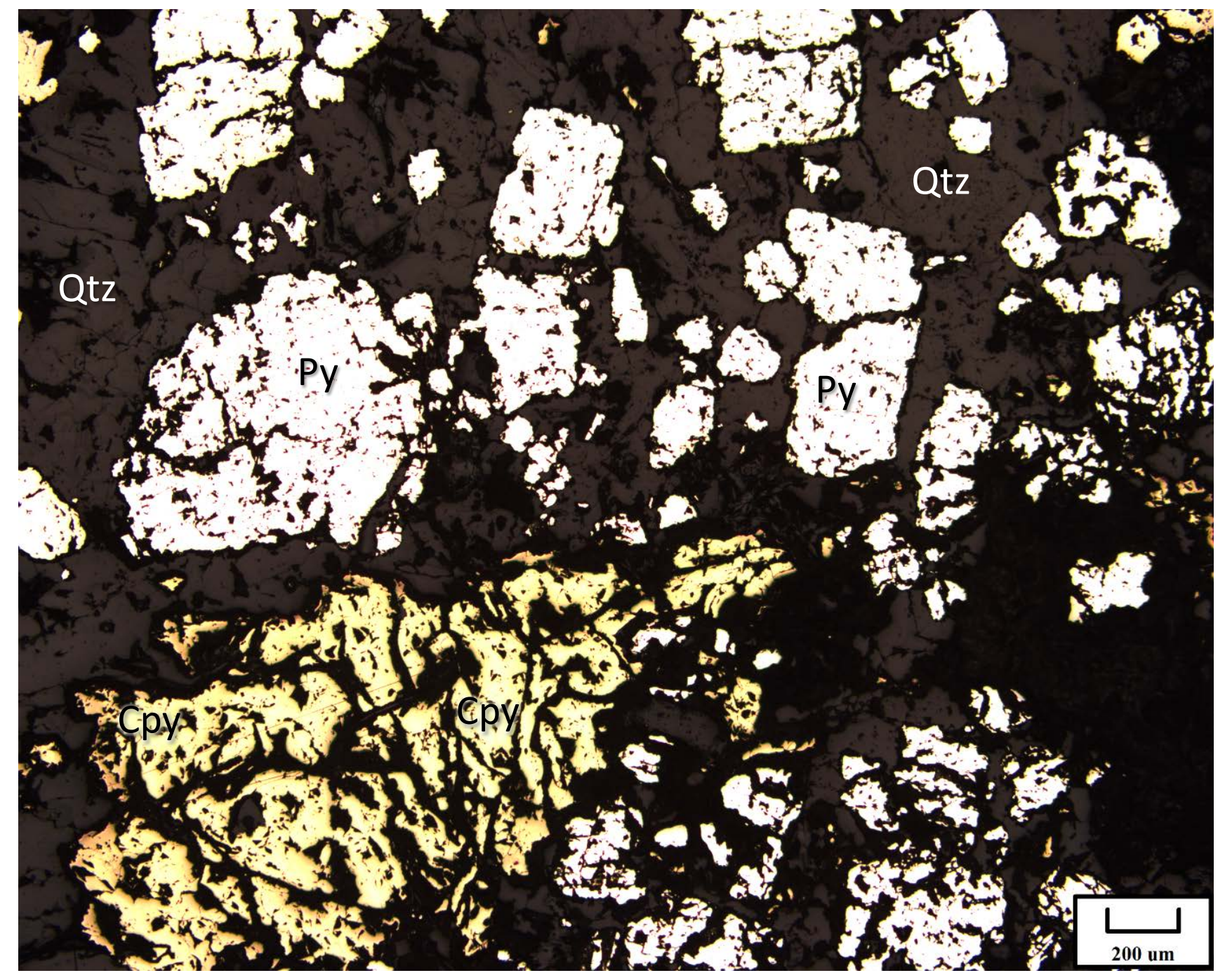

Fig. 9. Microscopic observation from a polished thin section from the weakly conductive site presented at fig.4. Assay returned 9.52% Cu over 3.5 feet. Resistive gangue minerals are isolating the chalcopyrite by filling the fractures.

This poster will be presented on: October 19, 2016 at 2:45 pm.

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References:

Parsons, S.R.G., Tremblay, R.G., and Avery, R.W., 2015, Bold Ventures Inc., Northern Superior Resources Inc., Lac Surprise gold project 2014 exploration program, Druillettes, Hazeur, Langloiserie Townships [NTS: 32G/6, 32G/7]. Internal Company Report.

Salmon, B., 1982, Distribution de la minéralisation d'une veine cuprifère sur la propriété de Falconbridge Copper Ltée à Chapais, P.Q, B.Sc.A thesis report, École Polytechnique de Montréal.