AEROTEM*: SYSTEM CHARACTERISTICS AND FIELD RESULTS

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The System

After about half a century of rapid AEM (airborne EM) development and application, the 1980's were a "decade of uncertainty" (Fountain 1998) wherein improvements focused mainly on increased bandwidth, multiple coil systems, and other advantages attendant on improved electronics and signal processing. An exception was the University of California, Berkeley UNICOIL cryogenic helicopter system which adopted a single coil as both transmitter and receiver. This array has been shown (Morrison et al, 1998) to maximize the ratio of target–to-host response in conductive environments. The UNICOIL system development was suspended in the early 1990's but the same principle was used by AeroQuest Ltd. in the AeroTEM * transient (time domain) AEM system (Figure 1), which places the receiving coil centrally within the transmitting loop, thus achieving the same coupling with ground conductors simultaneously in both coils.

Figure 1: AeroTEM 1 bird and helicopter

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This configuration has been shown (e.g Buselli, 1977) to have significant advantages over the loop-loop method in ground TEM (transient EM) applications, particularly in conditions of high ground conductivity. Among the advantages are: maximization of target-to-background response, simpler and sharper anomalies, enhancement of discrete conductors, and insensitivity to conductor strike direction. In addition, it has been shown by numerous authors (e.g.Smith and West, 1989) that the central loop configuration is optimally configured to excite a unique, negative response from bodies of modest polarizability. This feature is, in itself, a breakthrough of major importance in airborne prospecting since it is the first deliberate advance along the road to AIP (airborne IP).

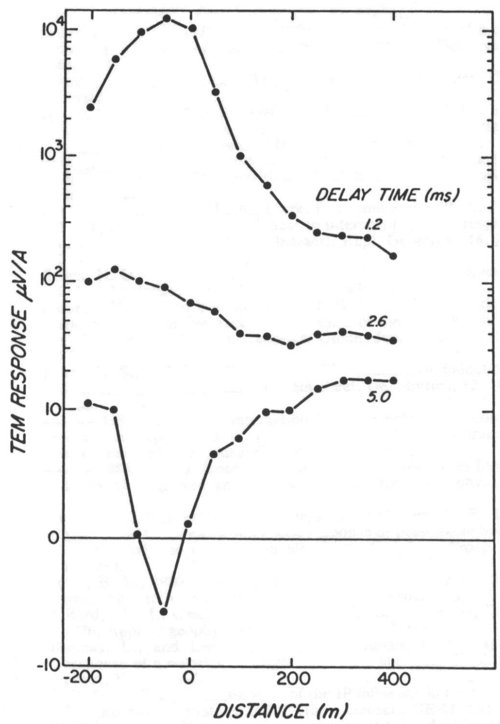

Figure 2: SIROTEM profile (McCracken et al., 1981)

AeroQuest Ltd., a Toronto-based company headed by Wally Boyko, founder of Aerodat Limited, began development of AeroTEM in 1996. Unique to the AeroTEM concept is the rigid mounting of the receiving coil, centrally within the transmitting loop. Other features include: a triangular current pulse of 1150 microsec, a base frequency of 150 Hz, a transmitting loop diameter of 5m, and orthogonal receiving coils (Z and X). Three hundred streaming records are recorded digitally per second, each record holding a single decay curve consisting of 100 samples of 16.6 microsecs width. The full wave-train is processed digitally off-line, to produce 12 channels of stacked and filtered data, commencing 64 microsecs (selectable) after current turn-off, with channel-widths varying from 50 to 483 microsecs. In addition, six channels of analogue data are recorded in flight, with channel-widths varying from 85 to 683 microsecs. These are displayed raw and, after flight, filtered and merged with GPS, altimeter and magnetometer data to provide field–ready stacked profiles.

The coil assembly, with associated electronics (Figure 1), is towed 50m below the helicopter and nominally 30m above terrain. In the AeroTEM 1 prototype, which made its first production flight in May 1999, transmitter current was 60 A, for a dipole moment of 18,000 NIA and a bird weight of 270 kg. In AeroTEM 2, which commenced operations a year later, dipole moment was raised to 45,000 NIA for an increase in weight of about 20 kg. Low in comparison with the transmitted moments of the fixed-wing, towed bird transient AEM systems, AeroTEM 2 provides comparable field strengths at normal prospecting depths, due to its much lower flying height. Additionally, the rigid coupling of the coil assembly allows anomalies as low as a few parts per billion of the transmitted field to be resolved in the received signal. Depth penetration to a moderate-sized conductor appears to be in the order of 250-300m.

Field Results

Approximately 5,000 line km of survey were flown with AeroTEM 1 in the period May-Dec, 1999. Attempts were made to combine routine survey applications with a comprehensive series of tests over known conductors of different types and in different environments, (e.g. Figure 3). The system proved to have all of the response characteristics built into the design.

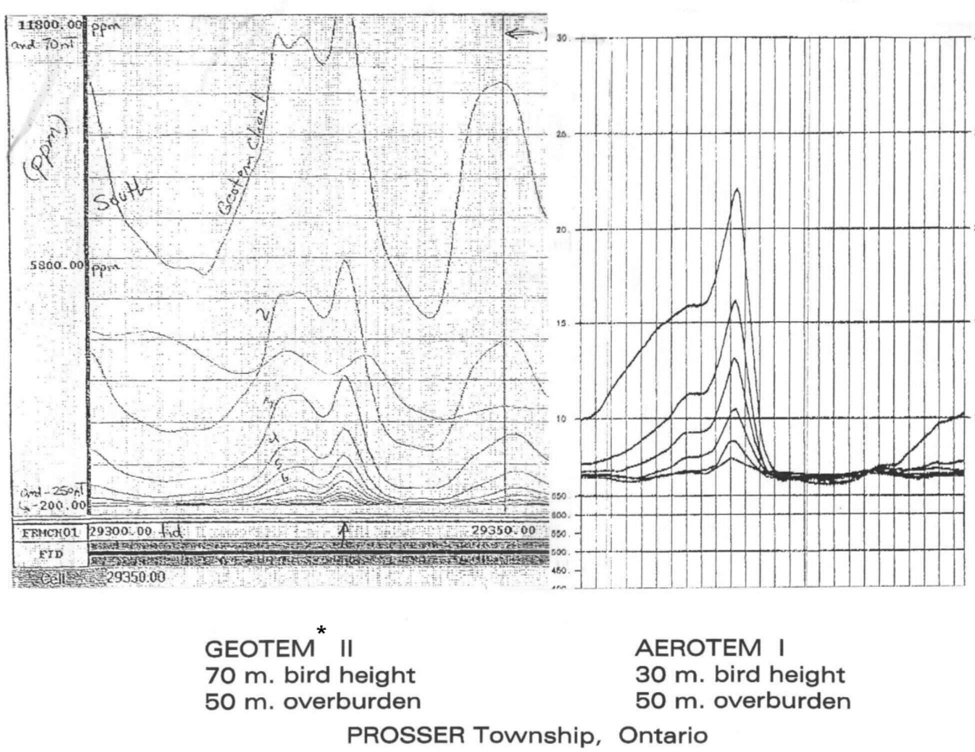

Figure 3: Prosser Twp., Ont. profiles (AeroTEM and INPUT). * Registered trademark of Fugro Airborne Surveys, Ottawa, Canada.

On an early survey, for Nuinsco Resources Limited in the Lac Rocher area of Quebec, a significant Ni-bearing sulphide body was clearly detected (Figure 4) where a previous survey by fixed-wing transient AEM showed no anomalies. The body was of short strike length and did not couple well with the N-S line direction of the earlier survey. In the same area a second anomaly was drilled and found to be related to a flat-lying lens of massive sulphides at a depth of 200m.

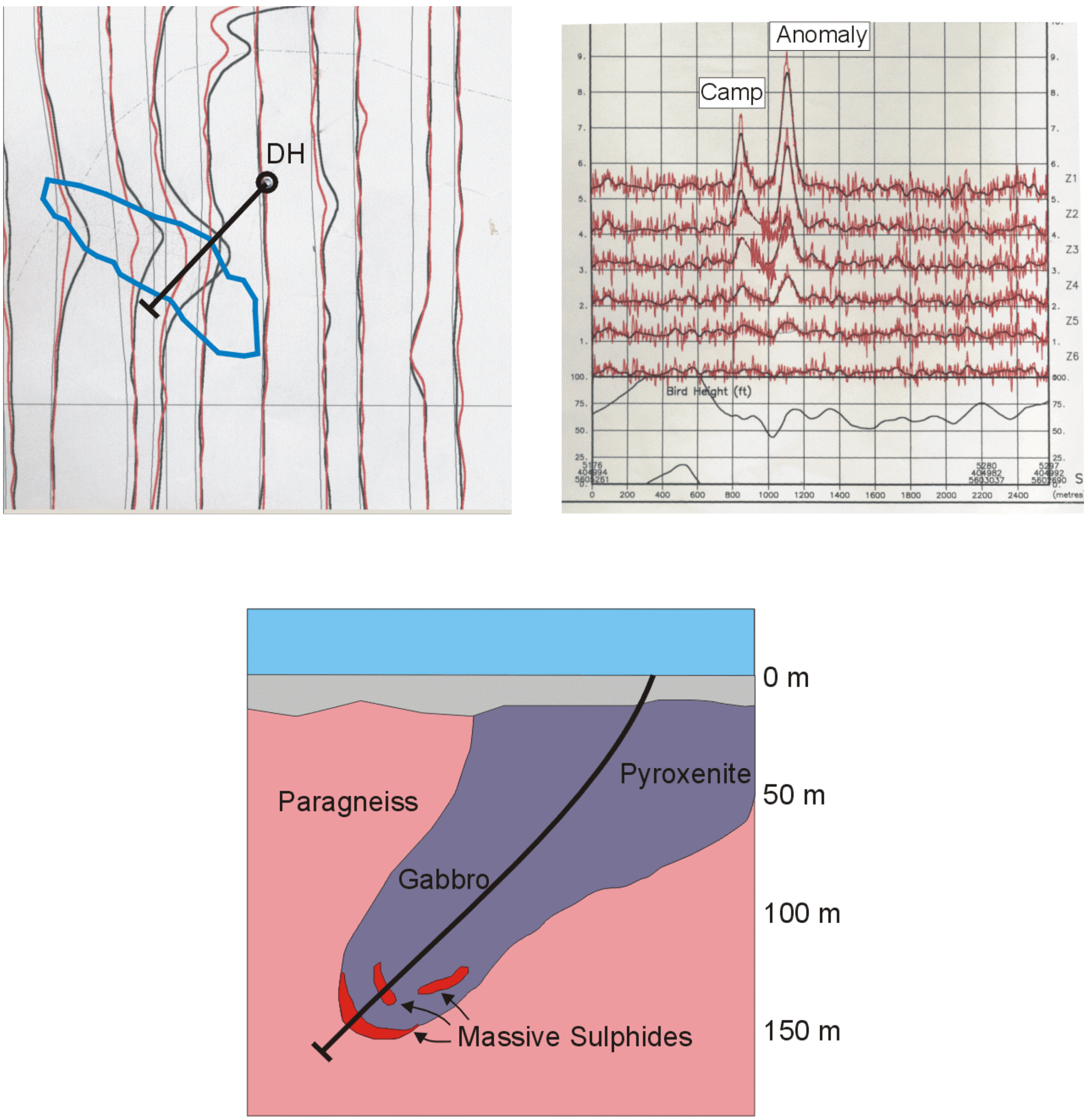

Figure 4: AeroTEM analog profiles and geology, Lac Rocher, Que.

On this and other surveys flown during the summer of 1999 the system consistently produced less overburden response, and a greater number of better-defined, clearer anomalies than had been obtained by previous surveys with both fixed-wing and helicopter AEM systems. Tests conducted in the Timmins area over Nighthawk Lake and other conductors familiar to the industry confirmed the smaller "footprint" of the system and its greatly enhanced anomaly to background resolution.

During these tests and on later surveys in Manitoba (Figures 5 and 6), a number of anomalies showed the characteristic reversal of sign in the later time channels common to central loop ground TEM systems. The occurrence of these was consistent, in the sense that a particular conductor would show the negative response on all intersections and in all flight directions while another, in an apparently similar geological and geomorphologic setting, would display entirely positive responses. There has been insufficient feed-back from drilling to satisfactorily explain the differences in sign.

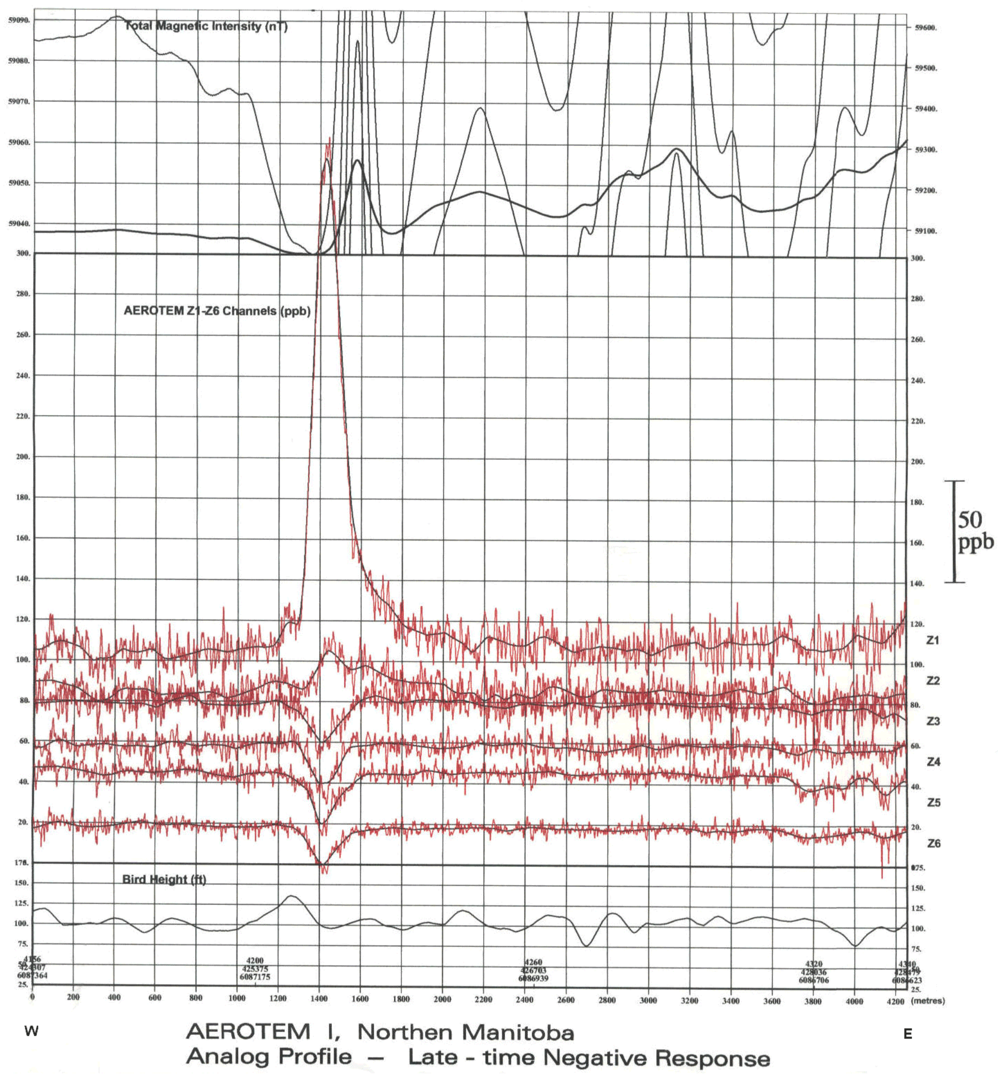

Figure 5: AeroTEM analog profile, Northern Manitoba; late channels negative.

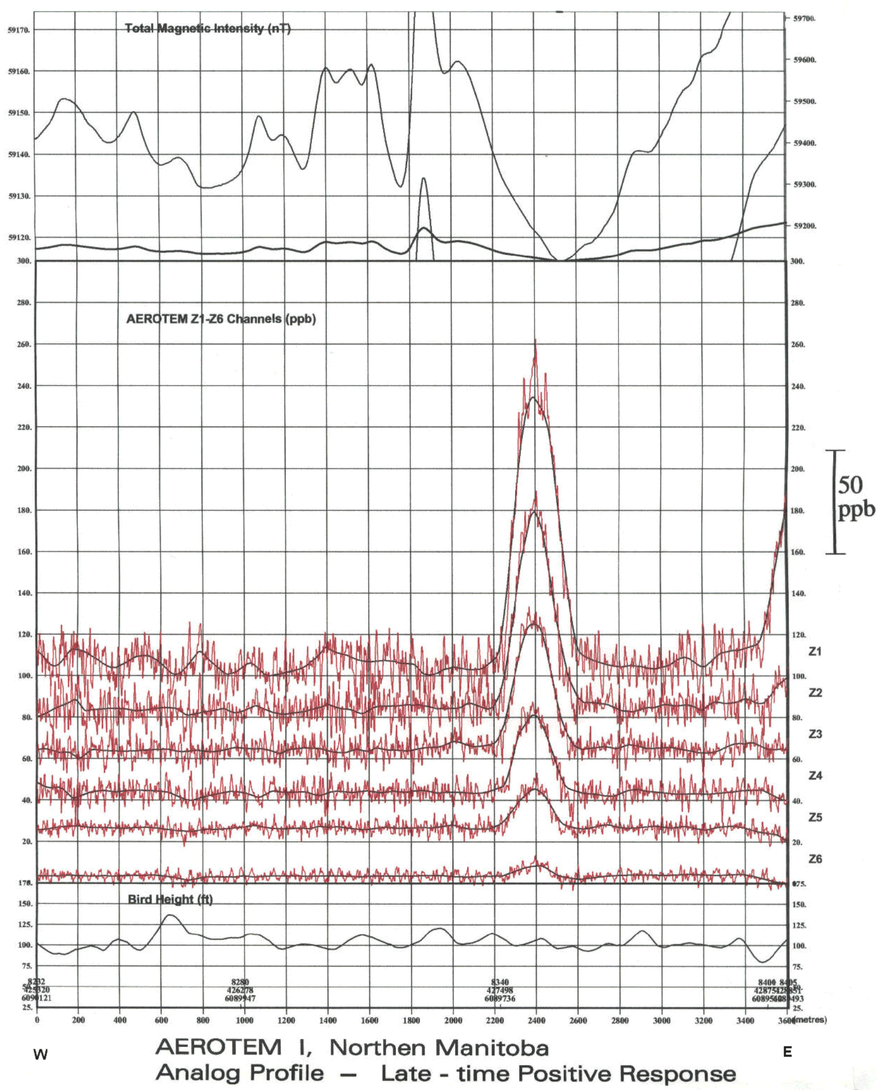

Figure 6: AeroTEM analog profiles, Northen Manitoba; late channels positive.

Important tests were carried out in the Lac de Gras area of the Northwest Territories, courtesy of Kennecott Canada Exploration Inc. Well-defined responses were obtained over most of the kimberlite pipes tested, comparable in strength (anomaly to background) to those of frequency HEM (helicopter EM), but with an apparently smaller footprint. Where pipes occurred under lakes, there was virtually no lake response in the early channels (Figure 7). Of particular interest was the rather large number of anomalies showing late channel negative responses. The Point Lake kimberlite showed distinct negatives in the last three analogue channels. A detailed test over the two Tli Kwi Cho kimberlites (DO 27 and DO 18) produced the very interesting results shown in Figure 7.

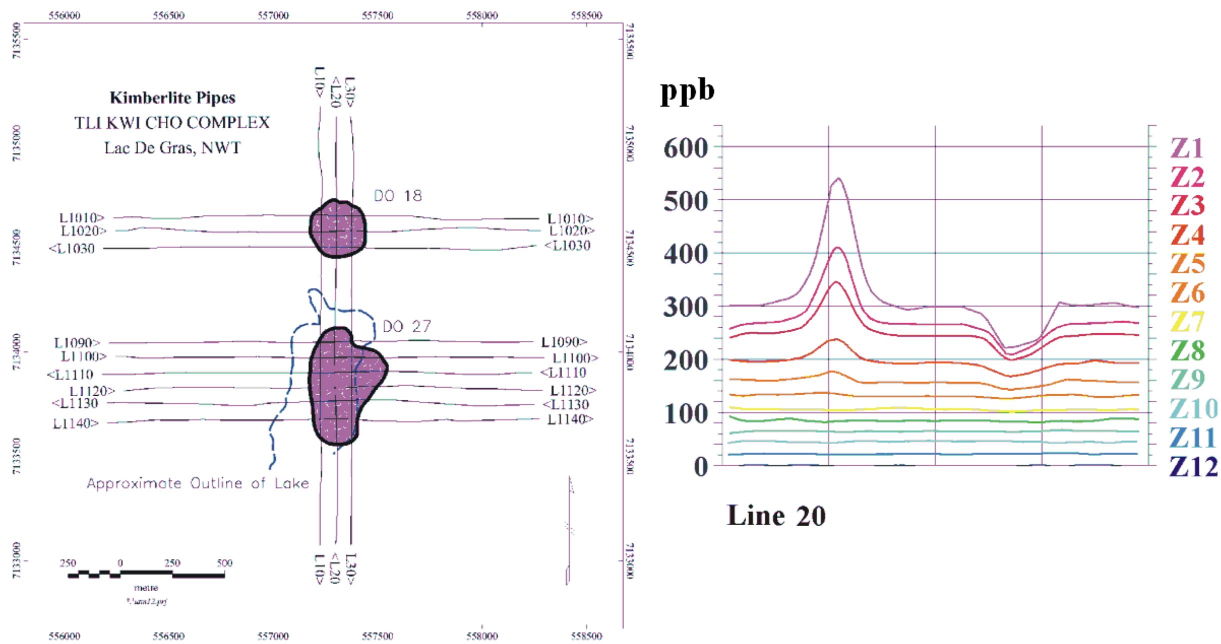

Figure 7: AeroTEM digital profiles over Tli Kwi Cho kimberlite pipes, Lac de Gras, NWT.

Kimberlite DO 27, which is under water, showed a mainly positive response, with faintly discernable negatives in the last two or three channels. By contrast, DO 18, on land to the north of the lake, produced an entirely negative response, decaying from early time to late. Such anomalies have been observed over kimberlites occurring in conductive rocks such as Cretaceous sediments, but this is not the case here where the country rocks are highly resistive. Furthermore, profiles recorded with the Dighem* HEM system showed perfectly normal and apparently identical anomalies over both pipes. Modeling tests, using reasonable values for IP and resistivity parameters show that the field results can be produced by a weakly conductive body of moderate chargeability. This would tend to suggest that DO 18 is polarizable while DO 27 is not. Geological studies of the two pipes do not show any reason why this should be the case, though DO 27 is reported as being more highly altered and therefore probably more conductive.

AeroTEM 2 results in early 2000 showed the expected improvement in response from deeper bodies. Profiles flown over the West MacDonald Mine (Figure 8), near Noranda, show a strong response at 210m elevation.

A limited test was conducted over the MNDM (Ministry of Northern Development and Mines) AEM Calibration Site in Reid and Mahaffy Townships, Ont. Figure 9 shows the AeroTEM Z coil response on Line 40, compared with the Z coil responses of three fixed wing systems and the coplanar responses of two HEM (helicopter EM) systems. The latter profiles were taken directly from the published MNDM report (Reford and Fyon, 2000), with the exception that the HEM low frequency profiles have been expanded

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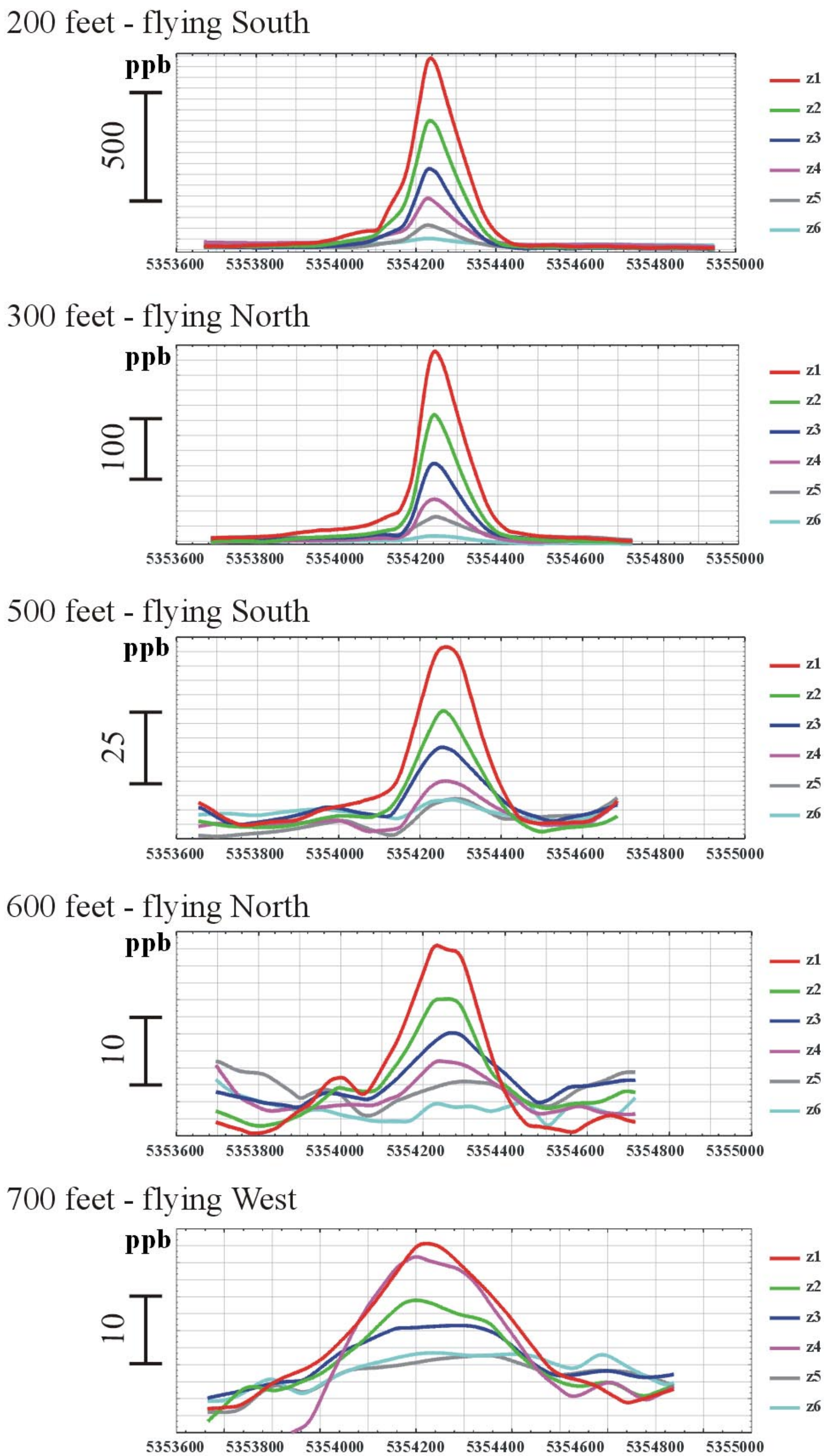

Figure 8: AeroTEM digital profiles over West MacDonald Mine, Noranda, Que.

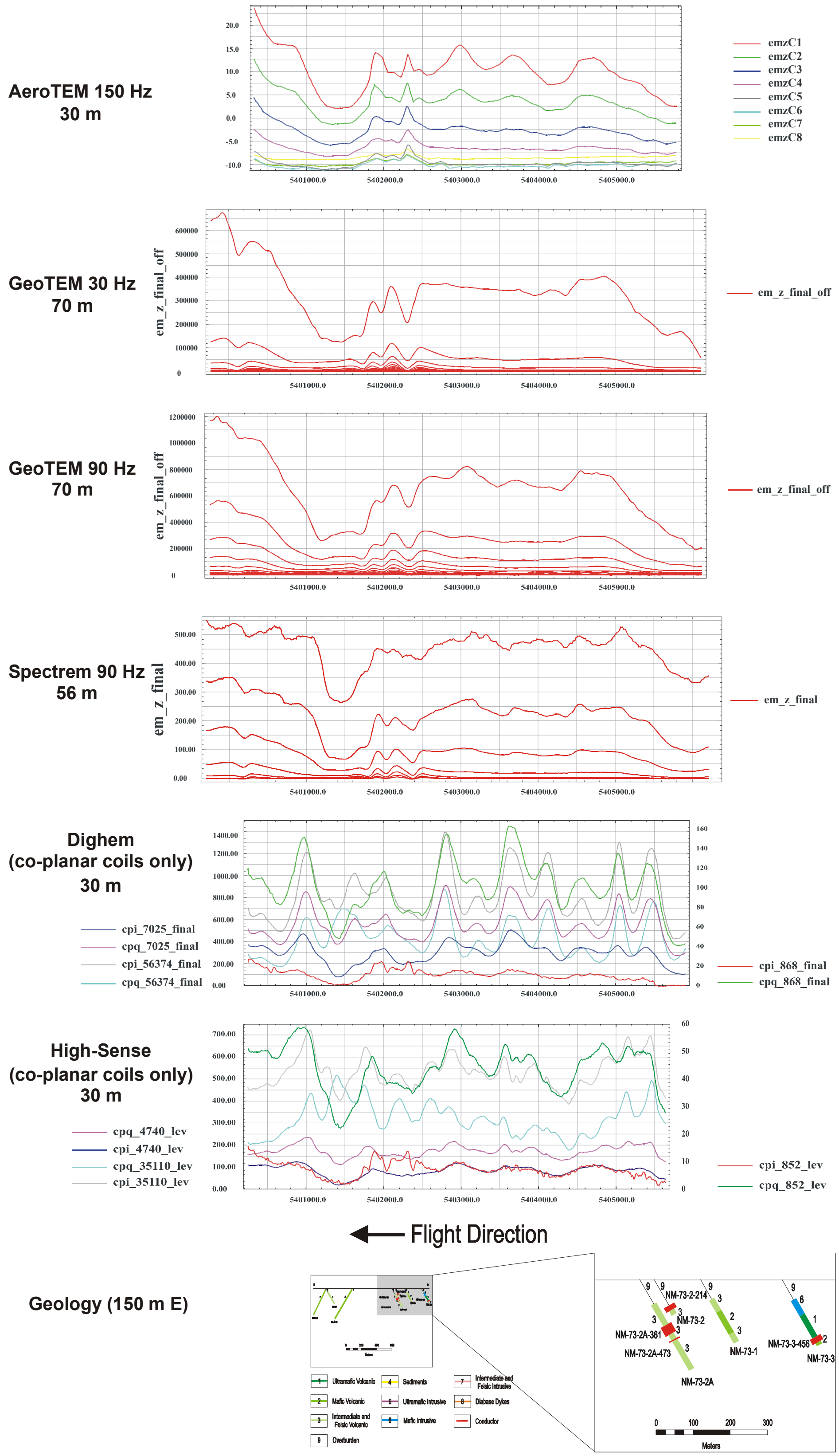

Figure 9: A comparison of AeroTEM 2 Z coil digital response, with five other commercial AEM systems, MNDM test site, Line 40, normal flying height.

vertically to a more appropriate scale. The AeroTEM responses compare favourably with those of the fixed wing systems in both resolution and target-to-background response. The HEM coplanar systems have far greater background response and are poorly coupled to the near-vertical conductors. The coaxial systems couple better and appear to come closer to matching the resolution of AeroTEM.

Figure 10 shows AeroTEM Z coil and X coil analog responses on the same profile, at an expanded scale. These can be used to compare with the published responses of the other systems on the MNDM website <www.gov.on.ca/MNDM/MINES/oth/index.htm> (Reford and Fyon, 2000) and the published report by Condor Consulting (Irvine et al., 2000).

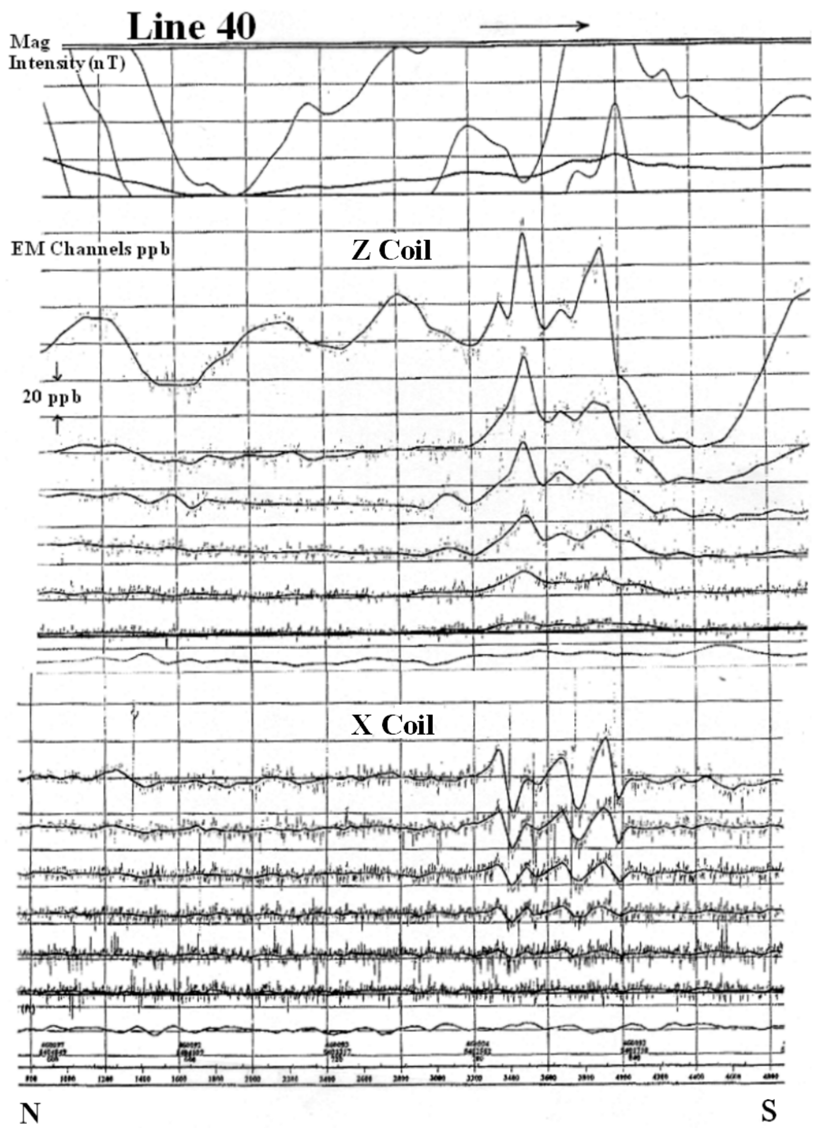

Figure 10: AeroTEM analog X coil EM and magnetic profiles, Line 40, MNDM test site, normal flying height.

Numerous tests were conducted with AeroTEM 2 in Quebec and Ontario during May-June 2000. One of note was a grid flown over the Noranda Inc. Perseverance sulphide deposit near Matagami, Quebec. This million ton deposit is less than 250 m in length and is apparently buried between 25 and 100 m below ground. It consists of a series of lenses strung out in a roughly northeast direction. An INPUT survey in 1986 flew directly over the body and failed to record a significant anomaly. It was detected by a recent transient fixed-wing AEM survey. AeroTEM 2 produced anomalies up to 30 times local background on 4 N-S and 5 E-W flight lines spaced 50 m apart. The AeroTEM anomaly appears to match perfectly the published outline of the orebody. The ability to contour AEM data regardless of line or conductor strike direction is unique to the AeroTEM system.

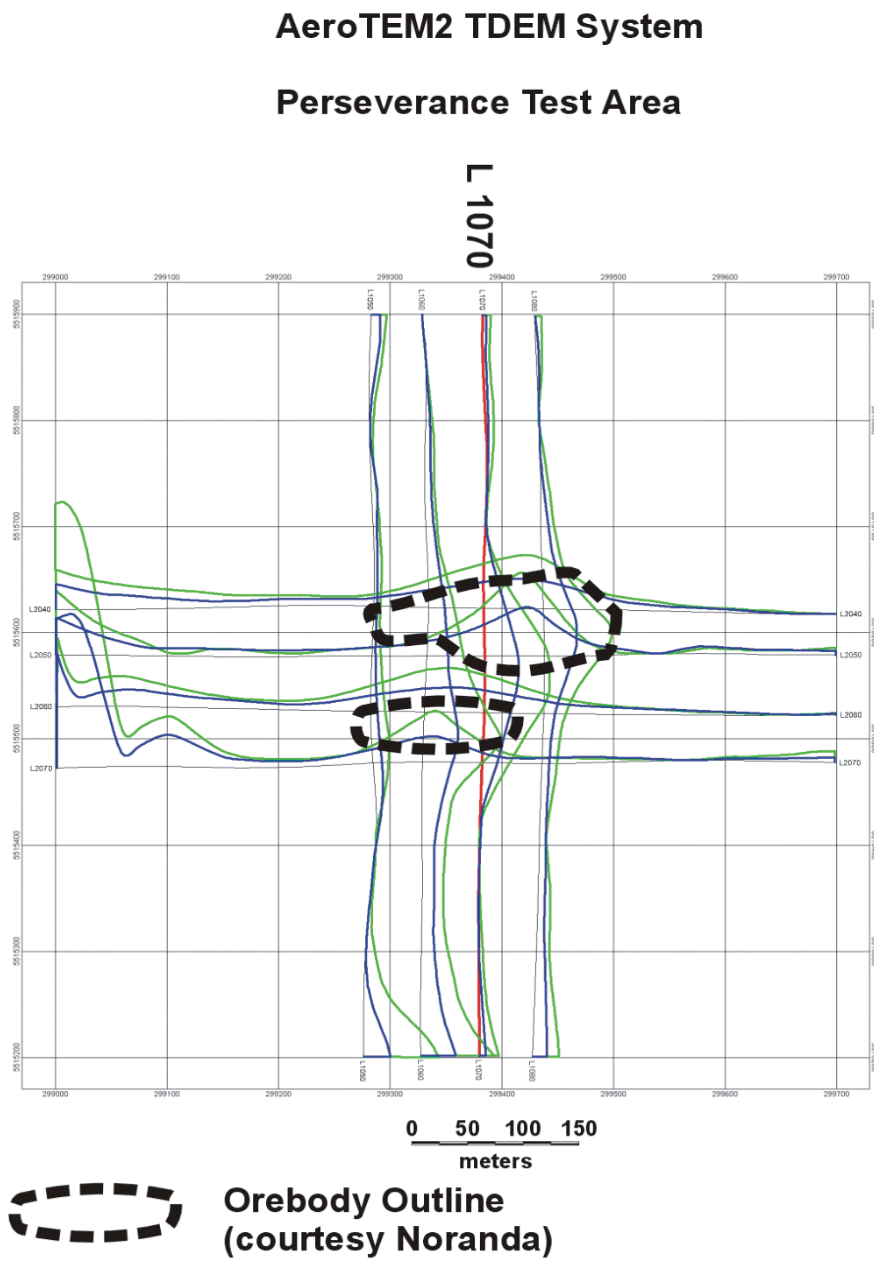

Figure 11: Perseverance profiles, EM z-axis channels one and three.

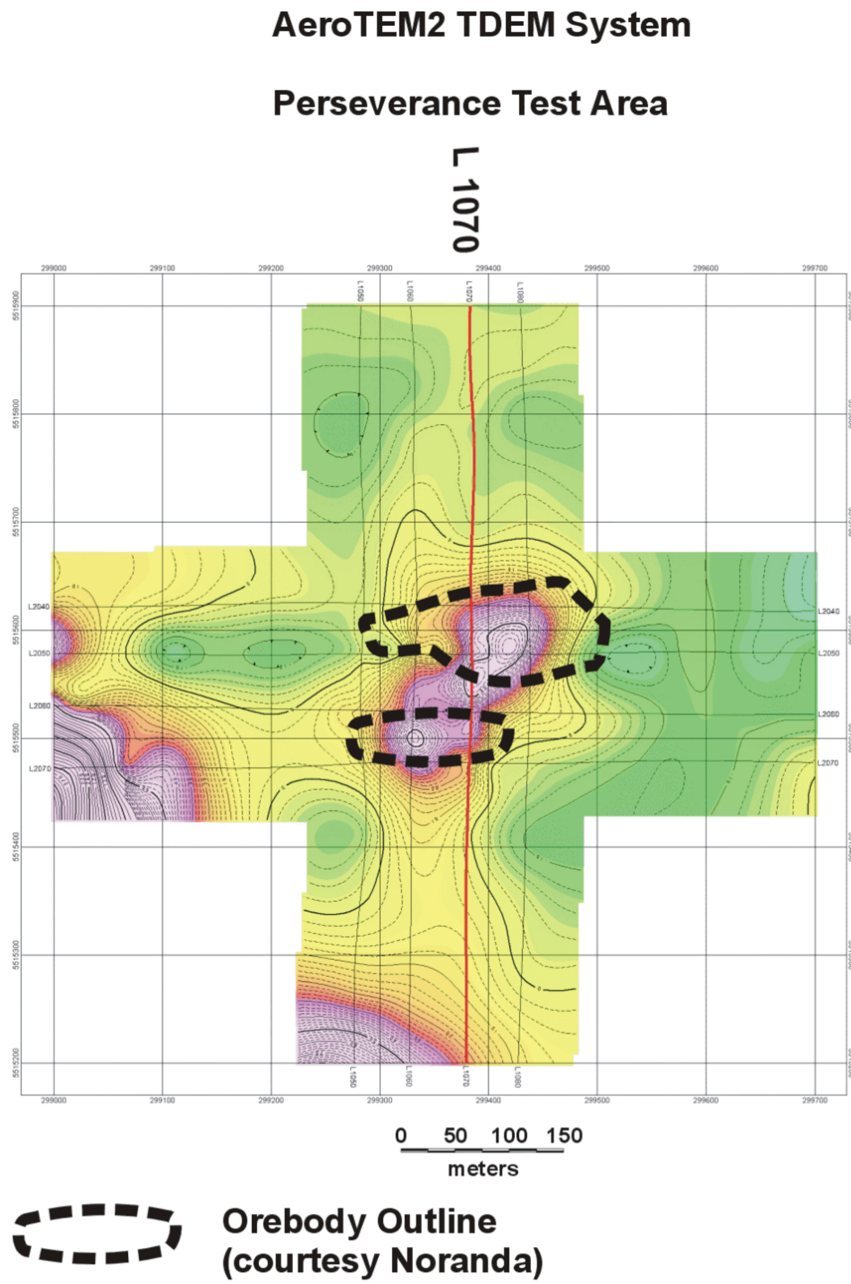

Figure 12: Perseverance grid, EM z-axis channel one contours.

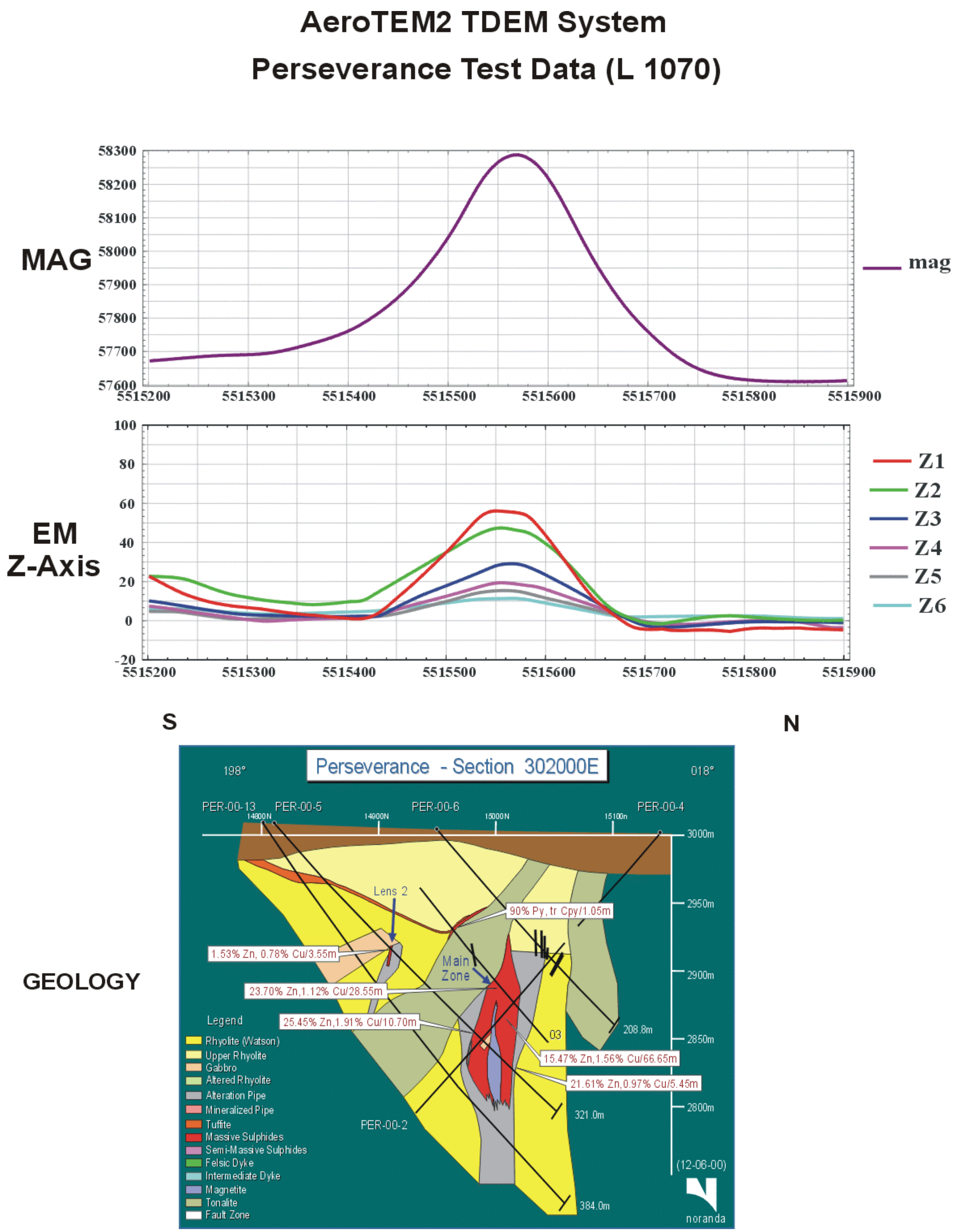

Figure 13: Perseverance AEM and magnetic profiles, and geology.

At the time of writing this paper, surveys and testing with AeroTEM (including a 30 Hz system) are continuing, and more field results will be available shortly.

Conclusions

In the one year that the AeroTEM system has been in operation sufficient evidence has been collected to demonstrate that it is not just a better AEM device but a significant breakthrough on several fronts:

1. The expected simplicity and clear footprints of the anomalies have proven of value in resolving conductors, particularly in areas of cultural interference or overlapping conductors .
2. Several important conductors of short and/or complex strike have been detected, where previous systems failed.
3. In conductive surficial conditions AeroTEM has revealed discrete conductors not discernable in previous surveys.
4. The system shows the potential to detect and recognize bodies that exhibit a form of polarizability, rather than simple electrical conductivity. Research on this is continuing but it seems possible that airborne IP is not far away.

A new AeroTEM system of still higher power is under design. Other features may include the ability to record B, rather than dB/dt, thus improving response to bodies of ultra-high conductance.

Acknowledgements

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