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Geophysical case history of the Hollandaire Copper Deposit, Western Australia

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SUMMARY

In 2011 a review of an historical TEMPEST airborne electromagnetic survey in the Murchison Region of Western Australia identified a number of discrete bedrock conductor anomalies potentially associated with base metal mineralisation. One of the anomalies identified was in close proximity to a known gossan at Hollandaire, within rocks of the Archaean Mt Eelya Complex. The Hollandaire gossan had been previously investigated during the mid-late 1970's using a variety of geological, geochemical and geophysical methods, including ground magnetics, induced polarisation, magnetic induced polarisation and time-domain electromagnetics.

A single line of time-domain in-loop transient electromagnetic data was collected at Hollandaire during 2011, in order to follow up the TEMPEST bedrock conductor. A strong time-domain EM anomaly was identified, with a very high time-constant of 107 ms. Plate modelling of the in-loop data resulted in a target at depth-to-top 100 m, dipping at 45 degrees to the west-northwest, and with conductance 5000 S. The nine initial holes drilled to test the electromagnetic target all intersected sulphide mineralisation. The inferred resource now totals 2.8 million tonnes at 1.6% Cu, 0.4 g/t Au and 5 g/t Ag, with the supergene zone averaging 4.7% Cu. Subsequent downhole electromagnetic (DHEM) surveys have identified an off-hole electromagnetic conductor to the south of the known mineralisation, which has not yet been tested by drilling.

Key words: TEMPEST, Time-domain electromagnetic method, Crone PEM, Hollandaire.

INTRODUCTION

In 2011, data from a 2003 TEMPEST AEM survey from the Tuckabianna area, Western Australia, was reviewed for the purposes of identifying anomalies potentially associated with base metal mineralisation. The review identified that a large number of anomalies had been picked and ranked as part of the survey report produced by Fugro Airborne Surveys (Sattel, 2004). A number of the highest-ranked anomalies were clustered in areas of conductive overburden and were disregarded. Six isolated, highly-ranked anomalies were recommended for ground follow-up using surface moving-loop time-domain electromagnetics (MLTEM).

METHOD AND RESULTS

The TEMPEST AEM survey over Tuckabianna was conducted with a flight line spacing of 200m in a WNW-ESE (119° – 289°) orientation. TEMPEST anomaly 9 on Flight line 10040 was one of the anomalies selected for ground follow up (Figure 1). The late-time TEMPEST X-component response and conductivity-depth image are shown in Figure 2. Anomaly 9 is located at Fiducial 1342. The time constant of the TEMPEST anomaly is ~7 ms, but this relatively small value is a consequence of the high base frequency and limited measurement time range of the AEM system.

At this stage of the project, no detailed surface geological data was available to help determine the strike direction of the TEMPEST conductor. TMI data acquired during the TEMPEST survey did not provide a clear indication of local strike, both because the host lithologies for the conductor are weakly or non-magnetic and due to the relatively coarse survey line spacing. There is no magnetic anomaly coincident with the TEMPEST conductor. Strongly-magnetic lithologies located ~2 kilometres to the East and West of Anomaly 9 strike roughly NNE. Close inspection of the TEMPEST data from the line 10030 immediately to the north showed a small, weak late-time X-component anomaly which possibly represented the strike extension of the stronger anomaly on Line 10040. This suggested an approximate N-S strike direction for the conductor, roughly consistent with the strike implied by the neighbouring highly-magnetic units. Accordingly, a 1.2 km surface MLTEM profile was planned in a 100°-280° orientation, designed to cross approximately perpendicular to the inferred conductor axis.

MLTEM data were acquired with a SMARTEM receiver and a Zonge NT-30 Tx, using a two-turn 150 m × 150 m loop and three-component fluxgate and dB/dt receivers. Station spacing was 75 m with some more detailed infill. Tx base frequencies of 1 Hz to 0.278 Hz were employed, yielding delay times of up to 710 ms. The late-time MLTEM dB/dt anomaly is shown in Figure 3. The time constant of the anomaly in the centre of the line is ~107 ms, indicating a high quality conductor.

Plate modelling of the in-loop data resulted in a target at depth-to-top 100 m, dipping at 45 degrees to the west-northwest, and with conductance 5000 S. The strike and dip extents of the modelled plate were 250 m and 75 m respectively. The strike direction of the conductor was constrained during modelling to be approximately north-south, given the weak TEMPEST anomaly on Line 10030, and the absence of any other geological control.

The nine initial holes drilled to test the electromagnetic target all intersected sulphide mineralisation, although at depths generally shallower than predicted by the electromagnetic model. The inferred resource now totals 2.8 million tonnes at 1.6% Cu, 0.4 g/t Au and 5 g/t Ag, with the supergene zone averaging 4.7% Cu.

Historical data

Subsequent to the initial geophysical surveys, interpretation, and drilling, records of earlier exploration at Hollandaire by Aquitaine Australia were unearthed (Gunn, 1977). These surveys included Crone Pulse EM (PEM) time-domain surveys, geological mapping and copper geochemistry.

A grid of slingram PEM lines was recorded over the conductor in east-west and north-south orientations, with a transmitter-receiver separation of 100 m and a station spacing of 50 m. The time-domain dB/dt response was recorded at 8 delay times ranging from 0.15 ms to 8.85 ms after the end of the current ramp. The transmitter loop size is not given in the report, but the effective depth of investigation of the instrument was estimated to be 100 m. The PEM anomalies identified by Gunn (1977) are shown as pink crosses on Figure 1.

TEMPEST flight lines 10040 and 10050 cross the PEM anomaly trend several hundred metres the WNW of Anomaly 9. No TEMPEST anomalies are observed at these locations, suggesting that the strongest bedrock conductor exists at the eastern end of the gossan outcrop.

Figure 4 shows the PEM data from East-West Line 13900N. The sign convention adopted for PEM data of this vintage is opposite to that used today: the response of a dipping platelike body shows a positive peak immediately over the top of the conductor, flanked by two negative lobes (Frischknecht et al., 1991). The asymmetry of the negative lobes indicates the dip direction, with the dip being toward the more negative lobe. Figure 4 indicates that the PEM conductor dips towards the left-hand (western) end of the profile at around 60 degrees.

The grid of PEM lines shows that the strike of the conductor near TEMPEST anomaly 9 is roughly northwest. This strike parallels the local strike of the surface gossan and the copper geochemical anomaly, but is inconsistent with the present geological model for the Hollandaire mineralisation which is a ~north striking tabular body plunging at approximately 30° to the south.

Revised MLTEM model

Several of the PEM anomalies are closely associated with the strong conductor identified by the TEMPEST and MLTEM surveys. However, the delay time range and late-time signal-to-noise ratio of the PEM instrument were insufficient to map the locally higher conductivity associated with the Hollandaire mineralisation, despite its relatively shallow depth. The initial 2011 MLTEM plate model shows relatively poor correspondence to the detailed geometry of the geological model and drilled mineralisation. This is most likely because the strike direction and extent of the model are poorly constrained by the single line of data.

Accordingly, the late-time MLTEM data were reinterpreted with the target attitude (but not lateral location, depth or strike/dip extents) constrained to be that of the geological model. This resulted in a smaller (78 m × 59 m) target of very high conductance (8400S) located near the centre of, and in the same plane as, the mineralised zone defined by drilling. The depth of the shallowest (northeastern) corner of the conductor is 58 m. This model produces an excellent fit to both the Z- and X-component MLTEM data (Figure 5), as well as an acceptable fit to the X-and Z-component TEMPEST anomalies. The revised plate model shows excellent correspondence with the highest copper grades encountered in the initial 9 drillholes, and likely represents the zone of most massive mineralisation (Figure 6).

Follow-up downhole electromagnetic (DHEM) surveys at Hollandaire have been conducted using the digiAtlantis three-component B-field probe. The DHEM log of hole 12HODD011 (Figure 1) indicates an off-hole conductor to the south of the known mineralisation, which is yet to be tested by drilling.

CONCLUSIONS

The TEMPEST and MLTEM data successfully identified a strong bedrock conductor at Hollandaire, located to the southwest of the gossan and PEM anomaly trend mapped by previous exploration during the 1970's. The initial nine holes drilled to test the TEM conductor all intersected copper mineralisation, although generally at shallower depth than predicted by the model. The initial model obtained from the MLTEM data, although of approximately the same lateral extent and depth as the now-known mineralisation, did not adequately match the detailed geometry defined by drilling. This was because of both the lack of geological control during the initial interpretation, and because the strike and extent of the conductor were poorly constrained by the single line of MLTEM data.

A revised interpretation of the MLTEM data was conducted with the target constrained to lie in the same attitude (dip, strike and rotation) as the current geological model. This resulted in a smaller, high conductance target which is closely coincident in depth and geometry with the highest copper grades encountered by drilling. The model shows excellent fits to the X- and Z-component MLTEM data, and appears to be adequately explained by the known distribution of mineralisation. DHEM surveying in drillhole 12HODD011 has detected an offhole conductor located south of the known mineralisation, which has yet to be tested by drilling.

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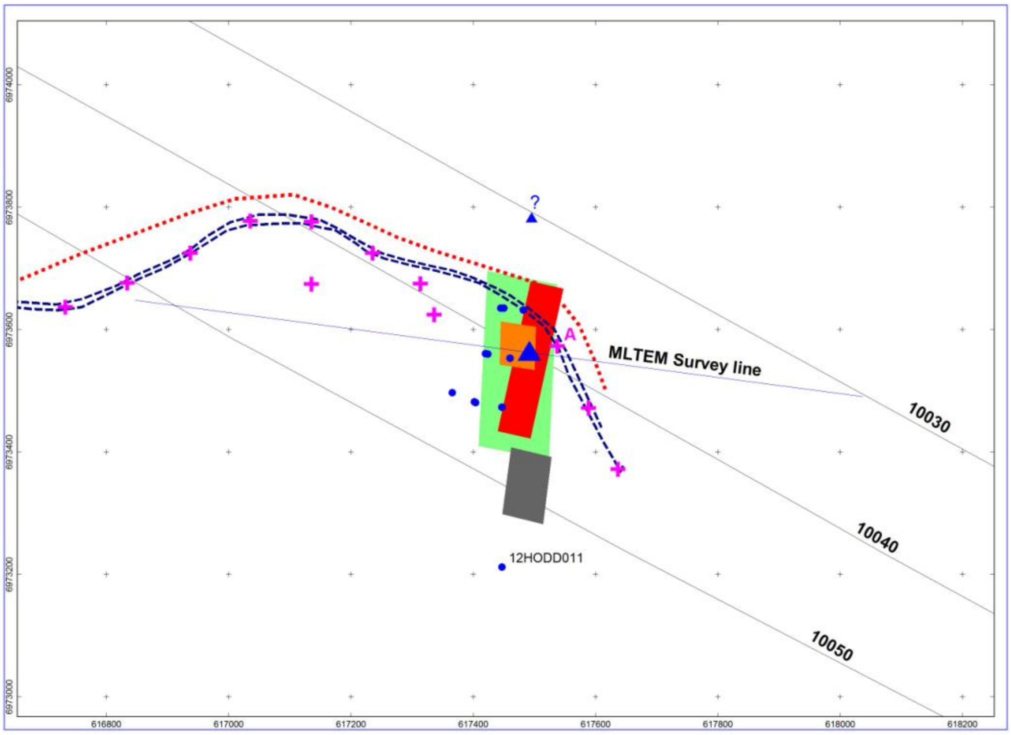

Figure 1 Plan view of the Hollandaire survey area, showing TEMPEST lines 10030 – 10050 and the MLTEM survey line. TEMPEST anomaly 9 on Line 10040 is shown by the large blue triangle, and the location of the much weaker anomaly on Line 10030 by the small triangle with the question mark. Dashed blue and dotted red lines show the gossan outcrop and axis of the copper geochemical anomaly respectively. Pink crosses show the 1977 PEM anomaly locations. Drillhole collars are shown as blue circles. Coloured polygons show the surface projections of the current mineralisation defined by drilling (light green), initial MLTEM model (red), revised MLTEM model (orange) and the DHEM conductor interpreted from the log of 12HODD011 (dark grey). Coordinates are MGA50.

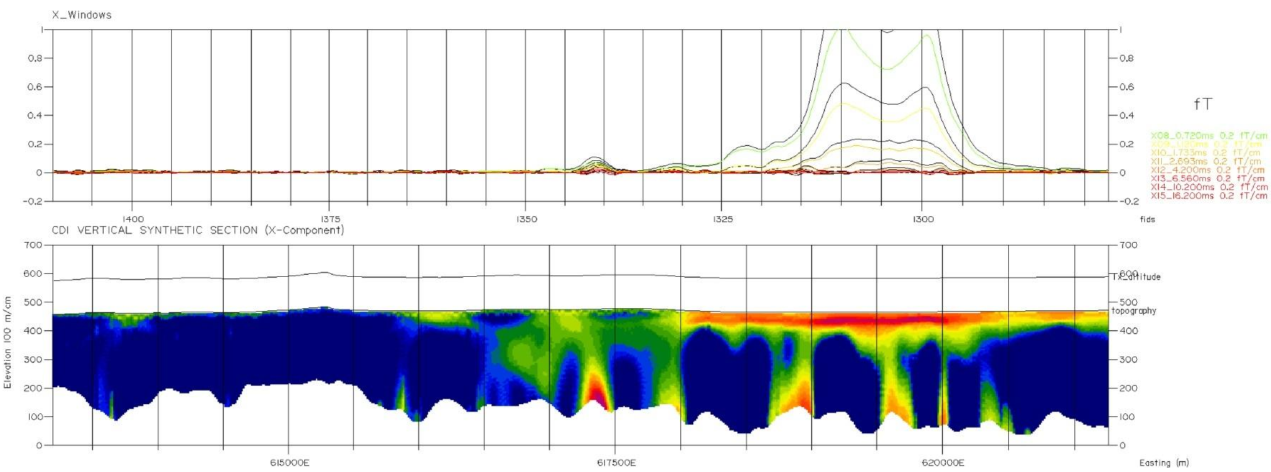

Figure 2 TEMPEST X-component response (top) and CDI (bottom) for Line 10040. Anomaly 9 is located at Fiducial 1342. Coordinates on the lower panel are AGD84.

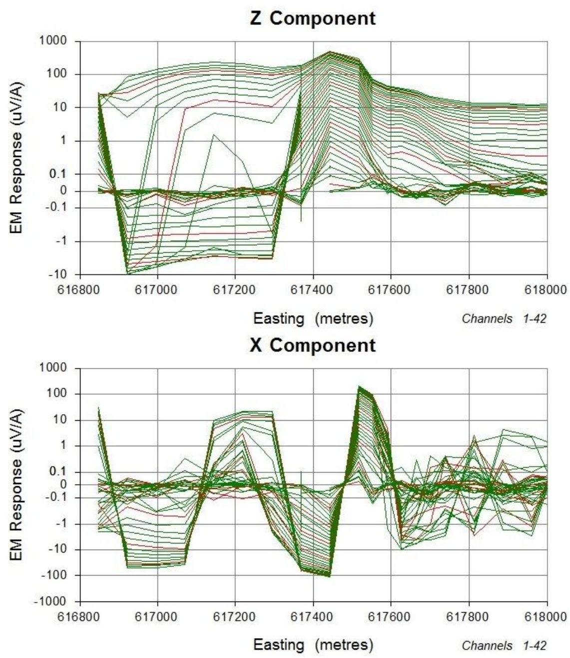

Figure 3 dB/dt in-loop MLTEM data acquired over TEMPEST anomaly 9 using a two-turn 150 × 150 m transmitter loop. The delay times shown range from 11 μs to 711 ms. The anomaly at ~617460E has a time constant of ~107 ms.

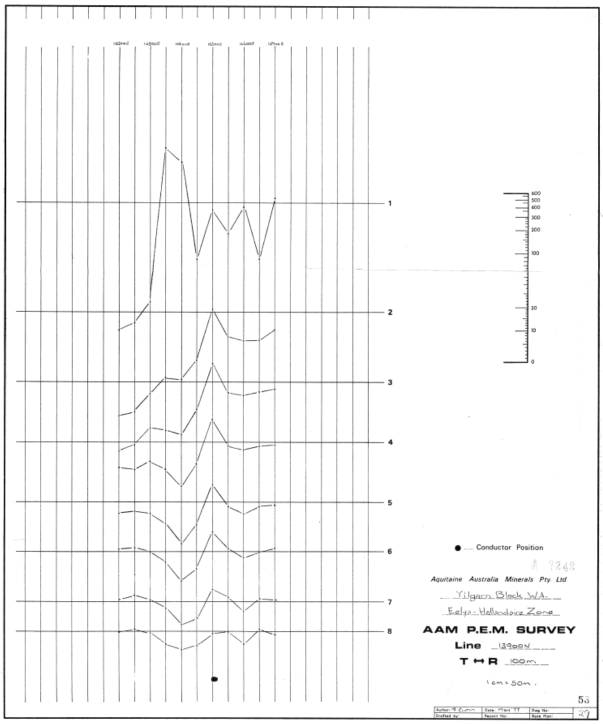

Figure 4 1977 moving-loop Crone PEM data from Line 13900N at Hollandaire, showing the closest PEM anomaly to TEMPEST anomaly 9 (labelled "A" on Figure 1). The conductor location interpreted by Gunn (1977) is shown by the black dot. The conductor dips towards the left-hand (western) end of the survey line. Delay times range from 0.15 ms to 8.85 ms after the end of the turn off ramp.

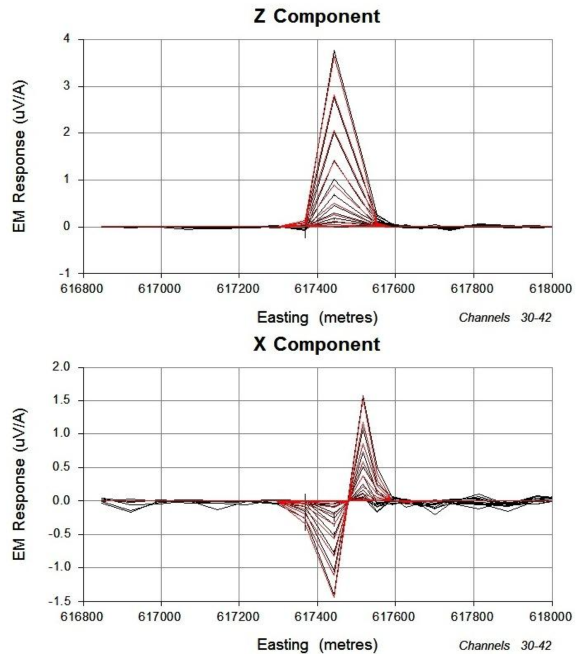

Figure 5 Response of the revised MLTEM model (red) compared to late-time field data (black), showing an excellent fit. Delay times shown range from 53 ms to 711 ms. The model geometry is shown in Figure 6.

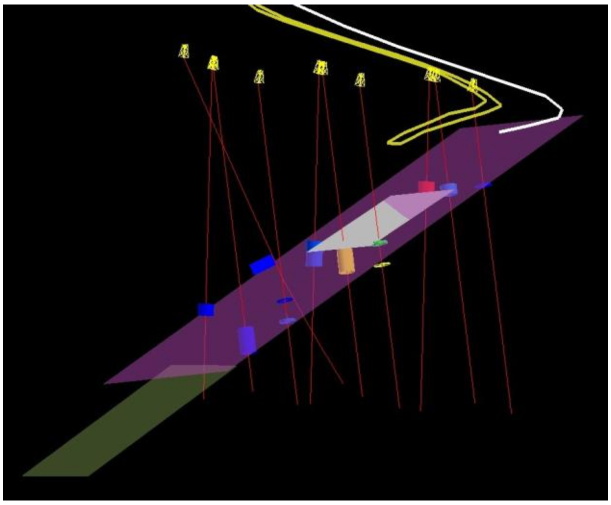

Figure 6 3D view of the Hollandaire EM interpretation, showing the drillholes (with copper assays as coloured cylinders). The current geological model of the mineralisation is shown in purple and the revised MLTEM model in light grey. The DHEM conductor interpreted south of the main mineralisation is shown in green. The yellow line shows the outline of the surface gossan, and the white line the outline of the copper geochemical anomaly. The colour scale for the drillhole copper assays is linear and ranges from 1% (dark blue) to 10% (red).