Vector Geoscience **Pty Ltd**
ABN 80 086 727 273

EXPLORATION GEOPHYSICS

PO Box 1133
Nedlands WA 6909
Perth, Australia

Phone: + 61 (0) 8 9386 8894
Email: vrgeosci@bigpond.com

sorell_vtem_TargetTEM_VR384.docx

Report No: VR384

Stunalara Metals Limited

Specialised Processing of VTEM data using TargetTEM™

Sorell, Tasmania,

Australia.

MAP REFERENCE: **TASMANIA SOUTH WEST SK/55**

KEY WORDS: **electromagnetics, TargetTEM™, TEM, time domain electromagnetic, VTEM**

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Data processing by: **Vector Geoscience Pty Ltd**

Job No: **VJ597**

Processing date: **August 2021**

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The conclusions and recommendations expressed in this report represent the opinions of the authors based on the data available to them. The opinions and recommendations provided from this information are in response to a request from the client and no liability is accepted for commercial decisions or actions resulting from them.

Survey Parameters

Survey name:	Sorell, Tasmania. Australia
Type of Data:	Transient Electromagnetics (TEM)
Survey datum:	GDA94 MGA Zone 55
Type of EM survey:	VTEM – 25Hz
Number of TEM channels:	36 (off-time channels = 13 to 48)
TEM receiver:	dB/dt and B-field
Receiver field components:	Z-component
Survey line spacing:	100+150+200 metres
Survey line direction:	Block 1 = 131 - 311 degrees (150 metres) Block 2 = 129 - 309 degrees (200 metres) Block 3 = 014 - 194 degrees (150 metres) Block 4 (Thomas Creek) = 090 - 270 degrees (200 metres) Block 5.1 = 164 - 344 degrees (100 metres) Block 5.2 = 116 - 296 degrees (150 metres)
Tie line spacing:	1,000+1,500+2,000 metres
Tie line direction:	perpendicular to survey lines.
Mean terrain clearance:	EM: Tx = 49 metres, Rx = 49 metres Magnetics = 74 metres
Survey distance:	1,243 km
Survey Date:	March 2010
Survey by:	Geotech Airborne Surveys
Job No.:	AA728
Survey commissioned by:	Macquarie Harbour Mining Limited.

Overview

TargetTEM^{TM} is a combined anomaly-detection and data-compression algorithm developed by Vector Geoscience to resolve detail in multichannel airborne transient electromagnetic (TEM) data. It is based on the premise that variations in the transient decay along the survey line are more important as indicators of exploration targets than the absolute response of the underlying geology. TargetTEM^{TM} can resolve detail in areas where the host rocks are conductive, and where a conductive overburden is present. TargetTEM^{TM} is a very convenient way of processing and displaying the very large volumes of data characteristic of all multichannel airborne TEM surveys.

TargetTEM^{TM} is a powerful mapping and data interpretation aid that is a basis for the geological interpretation of all types of TEM survey data. It is a new standard in geophysical data processing that is helping geologists to use complex, multichannel airborne TEM data from a wide variety of geological environments.

TargetTEM^{TM} can be applied to all types of airborne TEM survey data. It produces the TEMPORAL responses from the TEM decay response, which is described later. These are compressed into the EARLY-, MID- and LATE-time response channels convenient for integrating with other 2-dimensional datasets and for target identification. When both impulse response (dB/dt) and step response (B-field) data are available, their respective TargetTEM^{TM} responses are merged into COMPOSITE response data plots allowing accurate integrated analysis of both types of data. . Negative late-time decay channels, generally attributed to induced polarisation (IP) effects, are also displayed and integrated into the various TargetTEM^{TM} responses.

This report provides details of data processing using TargetTEM^{TM}.

TargetTEM^{TM} is another innovation from the research laboratory of Vector Geoscience.

TargetTEM^{TM} is a trade mark of Vector Geoscience Pty Ltd.

Stephen T. Mudge
Vector Geoscience Pty Ltd
Perth
Western Australia
Australia.

Contents

1 Introduction

1.1 General

TargetTEM^{TM} was developed by Vector Geoscience to resolve detail in multichannel airborne TEM data by discriminating anomalously conductive and anomalously resistive features from conductive overburden and conductive host rocks. It also compresses the large volume of complex multichannel data, characteristic of all airborne TEM surveys, into fewer channels that can be interpreted quickly and accurately by geologists.

TargetTEM^{TM} is a signal processing algorithm that detects and enhances variations in the measured signal. It operates on survey line data in preference to gridded data in order to preserve survey resolution. TargetTEM^{TM} is based on the premise that variations in the transient decay along the survey line are more important as indicators of exploration targets than the absolute TEM measurements at each location. In other words, variations in the responses are more important as exploration targets than the host rock response, the overburden response, and the calculated absolute conductivity of the sub-surface geology. TargetTEM^{TM} can resolve detail in areas where the host rocks are conductive, and where a conductive overburden is present. It can also map subtle high-frequency "textural noise", usually seen at late decay times, which can often be correlated with specific geological units. TargetTEM^{TM} resolves variations in the measured response and variations in the transient decay, it does not compute apparent conductivity/resistivity-depth sections. TargetTEM^{TM} produces higher resolution of conductivity variations in the sub-surface geology than most conductivity-depth algorithms.

TargetTEM^{TM} can be applied to any type of airborne TEM system, and either B-field or dB/dt data, and applied over any number of receiver channels. The algorithm is independent of the type of transmitter and receiver system used. It can be applied to on-time and off-time measurements and when both dB/dt and B-field data are available the responses for each data type are combined into a single response type.

The digital data files produced by TargetTEM^{TM} are identified by their respective response type. See the Appendix for a description of the file naming scheme used for the TargetTEM^{TM} output files. Details of the data file, plot files and the gridded data files produced from the work reported here are shown in the **List of Digital Files** given in the Appendix, and in the text file '**_TargetTEM_images.rtf*'. The data can be displayed with various GIS systems. The plot files are in *.dxf format, gridded data are in a standard grid format, and the images of the gridded data are standard bitmaps.

Sections 2 and 3 of this report describe the principles of time domain electromagnetics and the processing applied to the survey data by TargetTEM^{TM}.

See Section 4 for details on using the TargetTEM^{TM} results to identify anomalous conductors.

See Section 5 for an overview of the TargetTEM^{TM} processing for the survey data.

See the following Appendices for details of various aspects of the TargetTEM^{TM} processing:
Appendix 1 for explanation of the various measurements made by airborne EM systems,
Appendix 2 for explanation of the TargetTEM^{TM} computed responses,
Appendix 3 for explanation of the TargetTEM^{TM} products,
Appendix 4 for explanation of the conductor responses in TargetTEM^{TM} data,
Appendix 5 for description of the TargetTEM^{TM} database, and
Appendix 6 for description of the TargetTEM^{TM} output files.

2 Time Domain Airborne Electromagnetics

2.1 Principles of time domain measurements

Airborne time-domain EM is a complex science involving a variety of data types in several measurement directions (components) for a large number of data channels. The reader is referred to Dentith and Mudge (2014) for detailed descriptions of the TEM method, the responses of the various classes of conductors, and of the various techniques for the analysis and interpretation of TEM survey data.

In time-domain EM (TDEM), a current pulse (the on-time in Fig. 1a) applied to the large transmitter loop produces an electromagnetic (EM) *primary field* pulse that induces a circulating current flow, the circulating *eddy current*, into all conductive bodies coupling to this primary field. During the pulse off-time, the eddy currents, circulating in the various conductors, all decay with time as they expand through their respective conductors and loose energy due to the resistivity of the conductors. The decaying eddy currents produce their own magnetic fields, known as the *secondary field*. By measuring the amplitude and rate of decay of the decaying secondary field over time (Fig. 1b), it is possible to determine the conductivity distribution of the sub-surface geology. The rate of the secondary decay is diagnostic of the various classes of conductors.

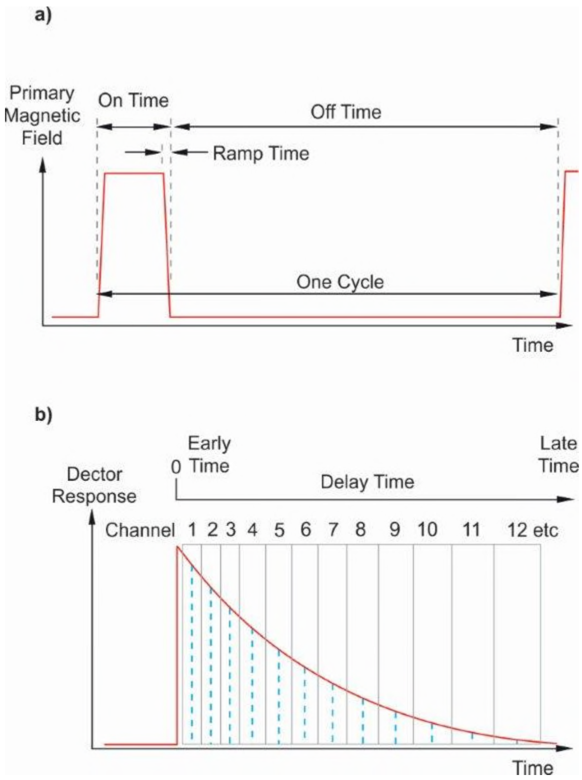

Figure 1. Schematic illustration of the basic time domain EM transmit-receive cycle showing (a) the on-time of the transmitted primary pulse and the off-time measurement period. (b) The receiver channels for measuring the decaying secondary fields at various delay times during the off-time period. Note that at early delay times the measurements (channels) are closer and narrower in time in order to accurately record this faster-changing part of the decay. Redrawn, with permission, from Dentith and Mudge (2014).

The penetration depth and resolution of EM systems are chiefly set by the shape of the transmitted pulse, the pulse turn-off or ramp time, and the timing of the receiver channels with respect to the turn-off of the primary pulse. Systems transmitting a square pulse are usually lower powered but provide good resolution of the near-surface and subtle conductivity contrasts. Deep penetrating high-powered systems have a 'rounded' pulse shape and sacrifice near-surface resolution and subtle conductivity resolution for greater depth penetration.

2.2 Unconfined conductors

Large regions of host rocks and large expanses of conductive layers, such as a conductive overburden, collectively produce the background response and have a characteristic fast EM decay, i.e. their strong response decays quickly with time (mathematically as a power law decay). These are known as unconfined conductors due to their unconfined (very large) physical dimensions.

Conductive overburden has the form of a horizontal conductive layer located on the surface and, therefore, produces strong responses in early decay times and has very fast decay (short decay time). The rate of decay becomes slower as the thickness of the layer increases (Fig. 2). The conductivity of overburden is usually fairly homogeneous, but its thickness is often variable, usually in accordance with changes in the underlying geology. It is common to identify anomalies within the overburden related to these changes in thickness.

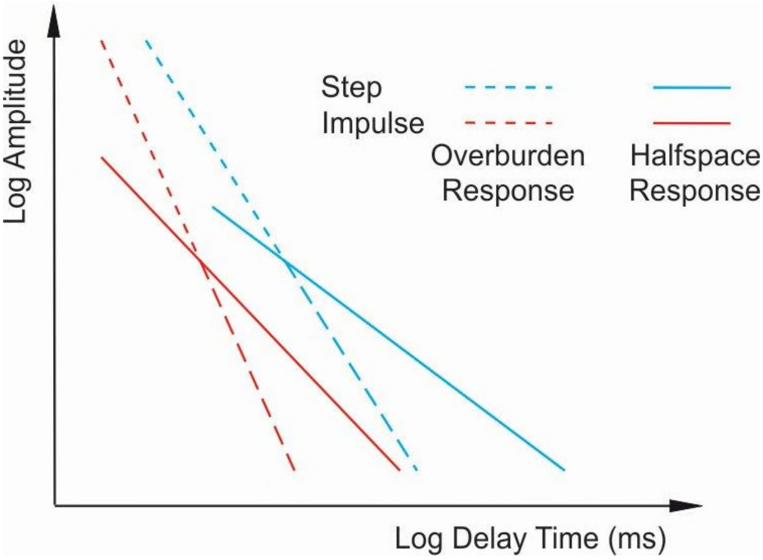

Figure 2. The secondary decays of a thin conductive layer, such as an overburden layer, and conductive background (a very thick layer) for the step (blue) and impulse (red) responses. Redrawn, with permission, from Dentith and Mudge (2014).

Due to their large size, excellent coupling with the transmitter loop and being close to the receiver, unconfined conductors produce strong responses. Their responses predominate at early decay times but, being fast decaying, are usually diminished by late times.

2.3 Confined conductors

Compact conductive bodies having higher electrical conductivity than the host rocks, referred to as confined conductors because of their limited physical size, produce a much slower decay rate (mathematically as an exponential decay) than the background responses of conductive layers and the host rocks.

Confined conductors with high conductivity and/or large size, have very slow decays extending to late delay times (Fig. 3) and are referred to as good 'quality' conductors. In contrast, those with low conductivity and/or small size have faster decay rates or shorter decay times, but still slower than the fast decaying background response, are referred to as poor 'quality' conductors. In summary, the rate of the secondary decay distinguishes between poor and good quality conductors.

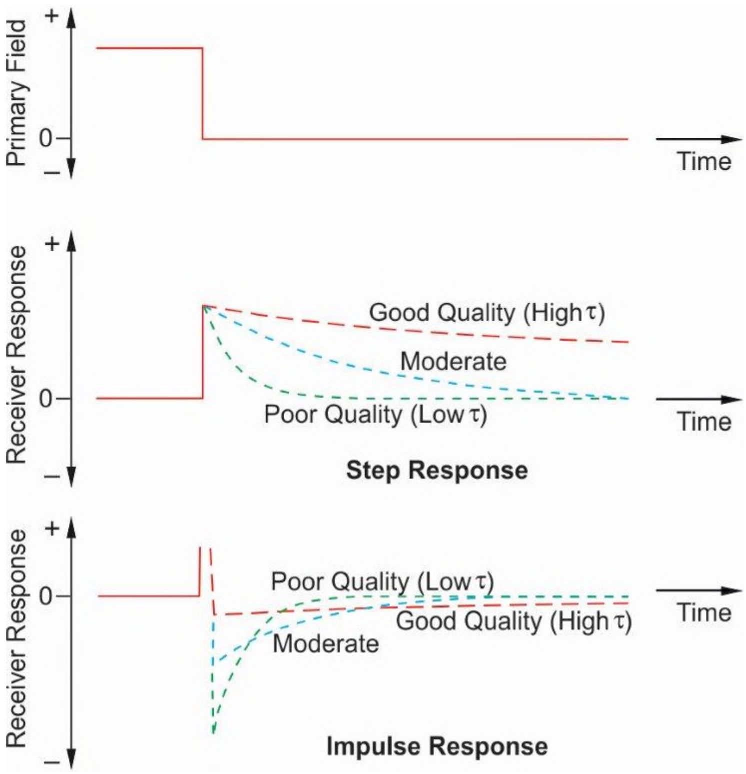

Figure 3. The secondary decays of a confined conductor of poor, moderate and good quality schematically illustrated for the step and impulse responses for a perfect step turn-off of the primary field. The reverse polarity of the impulse response is a consequence of it being the time-derivative of the step response. Redrawn, with permission, from Dentith and Mudge (2014).

The rate of decay is determined by the confined conductor's shape, size and conductivity, and the nature of the transmitted primary pulse. It is not dependent upon the depth or orientation of the conductor, nor the strength of the primary signal from the transmitter. Decay rate is fundamentally a reliable parameter for identifying the various classes of conductors. Note from Figure 3 that for the impulse response, poor quality conductors give a stronger response than good conductors, and that conductors of very high quality are invisible to the impulse response and only detectable in the step response.

2.4 Measured decays

In areas where the conductor is set in conductive host rocks, there will be two eddy current systems present, one circulating in the conductor and the other in the host rocks. Both contribute to the measured response. The background response (including that of conductive overburden if present) decays quickly during the early decay times leaving the slower decaying confined conductors (usually the target) to be resolved at later decay times (after the stronger, but faster decaying, background response has diminished).

Note that all classes of conductors have an early-time response, but only the good quality confined conductors have a late-time response. In areas where conductive overburden is not present, and where the host rocks are resistive and produce little response, the response of confined conductors can usually be seen across all decay times (the ideal situation). However, it is common to observe in survey data late-time responses without an associated response in the early-times of the decay. This is a sign that interference is occurring between neighbouring conductors, whose responses are likely to be dominate over particular time periods and may cancel out the decay or change its polarity (sign) for a period during the decay. This produces complex or 'noisy' decays.

Orientation of a conductor with respect to the EM system will determine the electro-magnetic coupling between the body and the system, and the amplitude of the measured responses as maybe seen in profiles and images of the raw survey channel data. The decay rate, i.e. the TEMPORAL response, is not affected by the strength of the induced field. Irrespective of the target-system geometry, the energy coupled into a conductive body will decay at a rate that discriminates poor and good conductors.

Sometimes the eddy current system in the confined conductor is galvanically connected with the current system in the host rocks allowing current flow from the host rocks into the conductor, and vice versa. This process is known as *galvanic coupling* or *current channelling*. Current channelling distorts the secondary decay and complicates interpretation of the data.

2.5 Survey height variations

Variation in survey height, which change the coupling between the transmitter loop and the various subsurface conductors coupling with it, is a common source of system noise. It causes both the strength and decay rate of the secondary signal to change as the distance from the transmitter loop to the various conductors changes, and causes the contribution of each individual conductor to the resultant secondary decay to change. Variations in the distance between the receiver and the ground contribute to changes in the strength of the measured signal.

The effect is most pronounced in helicopter survey data as the aircraft's height above the ground changes with variations in terrain and with wind conditions. Also, because the transmitter loop is in close proximity to the ground, height variations are commonly a significant fraction of the absolute nominal survey height above the ground. For the case of the higher-flying fixed-wing surveys, their more stable flight path and the greater height of the transmitter loop above the ground reduce this source of system noise. It is not possible to accurately correct for this source of noise, so it frequently appears in the earlier time channels, particularly in conductive environments, and common in all helicopter systems' data.

2.6 Induced polarisation effects

Induced polarisation (IP) is usually associated with clay minerals, graphite, carbonaceous shales, phyllites and sulphide mineralisation (Dentith and Mudge, 2014). The circulating induction currents interact with the IP effects of the host rocks and confined conductors to produce currents that circulate in the <u>opposite</u> direction to the induced eddy currents. These reverse circulating currents decay much slower than the EM-induced eddy currents and, therefore, extend to late times. They interact with the EM-induced eddy currents reducing the strength of the induced currents and increasing their rate of the decay. For most airborne EM systems, IP effects appear as negative polarity decays at late times when the EM-induced currents have diminished, i.e. the IP decay currents are then stronger than the EM-induced currents (Fig. 4). Note that when the IP decay currents are very strong, the amplitude of the induced EM response can be significantly reduced at early times producing a weak measured inductive response from the conductor.

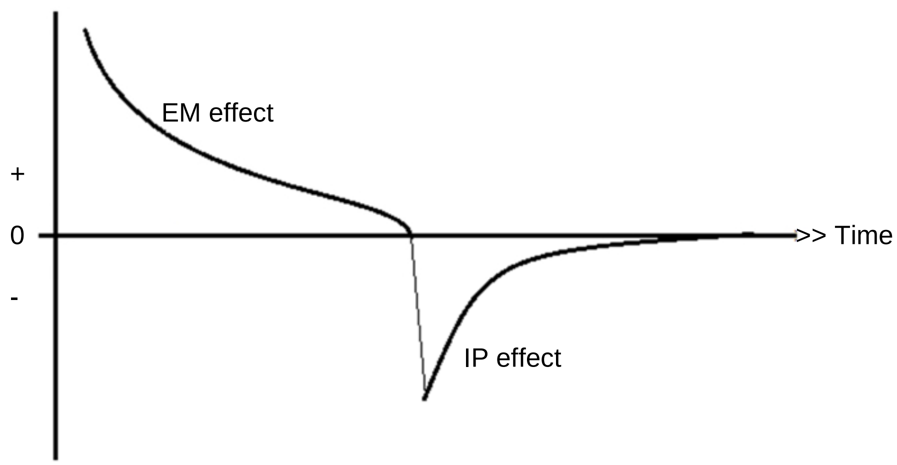

Figure 4. The secondary EM decay of a polarisable conductor with its slower decaying IP response appearing at late-times, and with opposite polarity to the EM decay.

2.7 Conductivity-depth images

Multichannel time domain airborne EM (TD-AEM) systems produce large volumes of data which presents challenges for displaying the data and for its interpretation. Several methods are used to display the data in ways that attempt to show the conductivity distribution of the sub-surface. These are based on computing the apparent conductivity/resistivity of the subsurface at the each decay time, at each measurement location along the survey line.

One class of algorithms is layered-earth inversion (LEI) modelling. LEI assumes that the conductivity structure of the ground at each measurement location is a series of horizontal layers of infinite lateral extent each having a particular thickness and conductivity. A second class of algorithms are known as conductivity-depth imaging (CDI). These are complex mathematical algorithms based on predicting the depth of the current flow at particular decay times and also assume that the conductivity of the ground has horizontal layering. Both classes of algorithms produce conductivity versus depth. The results of each type of conductivity/resistivity model can be displayed as 2D images at each decay time or depth respectively. They can also be displayed as pseudosections with decay time or computed depth increasing downward, or a group of pseudosections can be displayed as a 3D volume model of the sub-surface.

In areas of 3D geology, the assumptions of the above conductivity-depth algorithms, i.e. that the subsurface conductivity structure is layered, are clearly invalid and the computed conductivity/resistivity is inaccurate. The effect is to produce mathematical artefacts appearing as false anomalies in the pseudosections. In addition, current channelling and IP-effects, which also clearly do not conform to the assumption of layered conductivity, also produce mathematical artefacts in the pseudosections. Despite these limitations the models provide a convenient means of displaying the overall conductivity/resistivity distribution of the sub-surface. However, small and subtle conductivity features in the raw data, which can often be important exploration targets, get ‘lost’ in the computation of the various conductivity/resistivity models. The algorithms produce reliable results only when the conductivity distribution of the underlying geology conforms to the assumptions of each algorithm.

Importantly, the phenomenon of non-uniqueness, where many conductivity distributions, i.e. any number of layers of differing thicknesses and conductivities, can produce the same response, is a fundamental limitation on the ability of calculated conductivity/resistivity algorithms to accurately predict the true conductivity distribution of the sub-surface. In addition, the various algorithms available for producing CDIs and LEIs all produce different results (in detail) from the same dataset (by virtue of their different mathematics) increasing the uncertainty of the detailed analysis of the data. Examples of variations in computed CDIs and LEIs and artefacts produces within them are given by Peters et al. (2015) and Ley-Cooper et al. (2015).

Note that for the case when the receiver is located at the centre of the transmitter loop, as is the case for all the helicopter TD-AEM systems, there is no horizontal X-component response from a conductive horizontal layer, so only the vertical Z-component data can be used for LEI and CDI computations. Alternative techniques must be used to display and analyse in-loop X-component data.

3 TargetTEM™ processing

3.1 Variations in the secondary decay

TargetTEM™ resolves variations in the decay rate of the secondary field. Unlike CDI ad LEI techniques, it makes no assumptions about the conductivity distribution of the ground (it does not invoke an electrical model of the ground) and, consequently, it does not compute apparent conductivity/resistivity or depth.

At each delay time (decay channel), TargetTEM™ determines the variation in the decay relative to a representative background or reference response, which includes the responses of conductive host rocks and conductive overburden, at that delay time. Referring to Figure 5, the TargetTEM™ background reference value is ascribed a value of zero and shown in black. A thinner conductive layer (an unconfined conductor) has a faster decay than the background reference decay producing a negative TargetTEM™ response shown in blue. Thicker layers, and confined conductors, both have slower decays and produce a positive response shown in red.

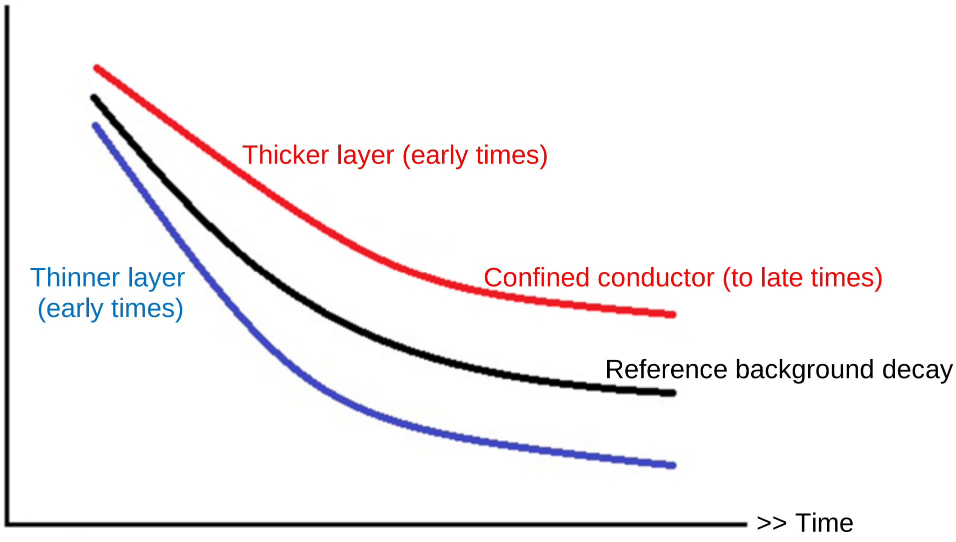

Figure 5. The TargetTEM™ reference decay shown in black and anomalous decays in red and blue.

TargetTEM™ is applied to the decay channel data of the survey line-data to determine the representative background response for the full dataset (whole survey area), and then produces the time-varying or TEMPORAL, responses of the ground. It has high sensitivity to thickness changes in a conductive layer, such as an overburden layer, and confined conductors located in the layer; and for resolving the weaker responses of confined conductors located below a conductive layer (providing the confined conductor has been energised by the EM system and is not entirely shielded by the overburden layer). These groups of confined conductors are often unresolved in methods that calculate apparent conductivity. TargetTEM™ detects and locates anomalous zones of conductivity detected by the EM system, without producing artefacts in the processed data.

TargetTEM™ also enhances short wavelength features along the survey lines, and associated large-scale linear and curvilinear features across the survey lines. It also resolves high-frequency textural signal often associated with near-surface conductivity features, such as conductive overburden, which is useful for delineating different near surface rock types and variations in the weathering environment.

Negative polarity decay values, generally attributed to IP effect, are detected by TargetTEM™ in Z-component data only. Decay channels showing IP-effect are flagged on the respective pseudosections in yellow. In addition, for every decay measured, the area of the negative part of the decay curve is taken as a measure of the intensity of the IP-effect, so a larger area is taken as being a stronger IP-effect than a smaller area. The data are displayed as a plan plot in yellow.

3.2 Computed responses

The TargetTEM^{TM} TEMPORAL responses can be computed for any type of EM system; i.e. IMPULSE response, STEP response or any other hybrid system; for ON-time and OFF-time measurements; and either for B-field or dB/dt data. Furthermore, they can be computed for any vector component of the measurement, such as the along-line horizontal (X) component, the across-line horizontal (Y) component, and the vertical (Z) component.

When both the STEP and IMPULSE response data are available, TargetTEM^{TM} compresses the data to produce the COMPOSITE response for each measured component. For the case when only the STEP or the IMPULSE response for both X- and Z-component data are available, TargetTEM^{TM} compresses the data to produce the TOTAL response. See Appendix 2 for details of both responses. TargetTEM^{TM} data are further compressed into EARLY-, MID- and LATE-time channels for displaying the spatial extent of the results and to allow numerical ranking of the computed responses for anomaly targeting.

In summary, the TEMPORAL responses are highly effective for identifying confined sub-surface conductors, small areas of conductive overburden, and variations in conductivity in an overburden. An electrically homogeneous overburden covering the entire survey area will be invisible to the TEMPORAL response. The TEMPORAL responses provide greater resolution of variations in the conductivity of the sub-surface geology than calculated conductivity/resistivity, and without any artefacts produced.

The TEMPORAL response is flagged as the ‘tm’ response, which forms part of the naming of the respective filter responses in the naming of their digital data files and plot their files.

It is important to note that features in the TEMPORAL responses are not suitable for quantitative analysis using conventional EM analysis and modelling techniques. Other data processing and modelling algorithms must be used to analyse the unfiltered measured response of selected TargetTEM^{TM} anomalies. It is intended that the various TargetTEM^{TM} responses only be used to resolve the presence of features which are anomalous with respect to the representative background response, and to assist the targeting of specific anomalies for further investigation by conventional means.

4 TargetTEM™ results

4.1 General

See Appendix 3.2 for details of GIS software suitable for accurately displaying the TargetTEM™ output plot files (these are AutoCAD *.dxf format files). Images of the gridded data can also be displayed and integrated with the bipole plots using this software. See the text file '**_TargetTEM_images.rtf*' for details of the processed data and the text file '**_linelist.txt*' for details of the survey lines.

Grids and images of terrain (DTM), survey height, magnetics (TMI), the high-pass filtered magnetics (TMI-HP), logarithm of amplitudes of the central raw EM channels comprising the compressed EARLY, MID and LATE-time channels, and the powerline monitor (PLM) channel are provided. Several colour images with different colour stretches, e.g. linear, histogram equalised and Gaussian stretches, are also provided to enhance image resolution. Greyscale images are also provide as these are very effective as the underlying layer when displaying the multi-coloured ranking plots and the various bipole plots.

See the following Appendices for details of various aspects of TargetTEM™ processing:

- Appendix 1 for measurements made by airborne EM systems,
- Appendix 2 for TargetTEM™ computed responses: COMPOSITE, TOTAL, EARLY-MID-LATE, EM-anomalies, anomaly RANKING and IPLEVEL,
- Appendix 3 for TargetTEM™ products: Bipole plots, bipole plot display software and XYZ data,
- Appendix 4 for conductor responses in TargetTEM™ data: geological conductors, conductive overburden, and other processes effecting conductivity measurements,
- Appendix 5 for TargetTEM™ database, i.e. the digital file directories and the files contained within them, and
- Appendix 6 for naming conventions of the TargetTEM™ output files.

It is important to note that features in the TEMPORAL responses are not suitable for quantitative analysis using conventional EM analysis and modelling techniques. Other data processing and modelling algorithms must be used to analyse the unfiltered measured response of selected TargetTEM™ anomalies. It is intended that the various TargetTEM™ responses only be used to resolve the presence of features which are anomalous with respect to the representative background response, and to assist the targeting of specific anomalies for further investigation by conventional means. Usually ground EM surveys are recommended to further investigate anomalous zones targeted with TargetTEM™.

4.2 Using TargetTEM™ results

The survey data comprise both dB/dt Z-component and B-field Z-component data for 36 channels:

1. View the EManoms bipole plan file '**_CZ_RR_EManoms_pln.dxf*' to display all the anomalous conductivity zones. This shows the distribution and lateral extent of all the regional-removed conductivity zones resolved by TargetTEM™.

2. The spatial distribution of the IP-effect can be integrated with all the various data channels by displaying the plan file '**_BZ_IPlevel_pln.dxf"* (IP level is shown in yellow, see Section 2.6).

3. To target confined conductors, view the COMPOSITE (C) response ranking (see Appendix 2.5) plan file '**_CZ_RR_RankTopXX.dxf*', where 'XX' is the ranking level ('01', '02' or '05' etc %). Start with the 1% ranking level ('01'). Overlay this on the greyscale TMIHP and TMI images (when available) and geological plans to investigate the geological significance of the various ranked anomalous zones. Red zones are indicative of the best quality conductors detected, decreasing through green zones, with blue being the poorest quality. Note that the effects of survey height variations (see Section 2.5) can be quite pronounced in the earlier time channels, so there maybe correlations with variations in the HEIGHT and DTM (greyscale) images. Repeat for higher ranking levels, and for the selected ranking intervals (plan files '**_CZ_RR_RankXX-YY.dxf).*'

4. To investigate the distribution of confined conductors along a particular survey line, or to investigate further the response of a target conductor, overlay the survey lines plan file (‘*_RR_survey_lines_pln.dxf*’) and identify the survey line number, then view the regional-removed (RR) pseudosection plot file of the COMPOSITE (C) response for that survey line; file name ‘*_CZ_RR_Lnumber_tmCH_lin.dxf*’. The cyan zones delineate the conductive zones. Conductors with higher conductivity/size will respond to later times. Check the profiles of TMI and TMIHP for correlations with the EM responses to assist with evaluation of the EM response, and check the profiles of DTM, HEIGHT and POWERLINE (PLM) for correlations that may indicate these as the source of the EM response. The location and width, and possibly dip direction, of the EM responses can be ascertained from the pseudosection. Note that the real-world co-ordinates of the horizontal axis tic marks are given in the associated co-ordinate text file (‘*_lin_xen.txt*’). To view the anomaly ranking along the survey line, display the ranking overlay plot for the respective survey line, file name ‘*_RR_Lnumber_tmRK_lin.dxf*’ (see Appendices 2.5 and 3.1). See Appendix 3.2 for details of displaying pseudosection and plan plots simultaneously.

5. To investigate the distribution of confined conductors across a group of survey lines as a 3D data volume, view the regional-removed (RR) pseudosection 3D-located plot files of the COMPOSITE (C) response for the selected group of survey lines; file names ‘*_CZ_RR_Lnumber_tmCH_loc.dxf*’. The cyan zones delineate the conductive zones. Note that 3D viewing software is required (see Appendix 3.2). Note, 3D-located plot files not supplied.

6. To investigate the spatial extent of confined conductors, view the bipole plans for the regional-removed (RR) EARLY, MID and LATE time channels for the COMPOSITE (C) response; plot files ‘*_CZ_RR_tmEARLY(MID and LATE)_pln.dxf*’. The cyan zones identify the conductive zones. Conductors with higher conductivity/size will respond to later times. Overlay these plans on the TMI and TMIHP greyscale images to assist with evaluation of the EM response, and overlay them on the HEIGHT, DTM and POWERLINE greyscale images for correlations that may indicate these as the source of the EM response.

7. To investigate the spatial extent of conductive layers, such as conductive overburden and wide erosion channels, and to identify geological contacts exhibiting contrast in conductivity, view the bipole plans for the EARLY and MID-time channels; plot files ‘*_BZ_tmEARLY(MID)_pln.dxf*’ for the best overall resolution, and ‘*_dBdtZ_tmEARLY(MID)_pln.dxf*’. Black zones indicate the TargetTEM™ background (reference) values, blue zones indicate conductive layers thinner than the background zones, and red indicates thicker conductive layers. IP effects (see Section 2.6 and Appendix 4.3) may be resolved in the Z-component data and are displayed on the line pseudosection plots as yellow zones. Estimates of the depth and conductivity of the layers can be obtained from layered-earth inversion (LEI) images and/or conductivity-depth images (CDI).

8. To investigate the spatial extent of narrow conductive erosion channels, which may be associated with conductive overburden, view the bipole plans for the regional-removed (RR) EARLY and MID-time channels for the COMPOSITE (C) response; plot files ‘*_CZ_RR_tmEARLY(MID)_pln.dxf*’. Overlay these plans on the TMIHP greyscale images to assist with evaluation of the EM response, and overlay them on the HEIGHT, DTM and POWERLINE greyscale images for correlations that may indicate these as the source of the EM response.

9. Images of the logarithm of the amplitudes of the EM channels central to the EARLY, MID and LATE-time channel groups can be integrated with the various bipole plan images.

10. Note that the bipole PSEUDOSECTION plots **are NOT depth-sections, they are pseudo-time sections using channel number as a proxy for delay time**.

11. Anomalies due to highly conductive **cultural features** such as metal buildings, water tanks, silos, drilling rigs, headframes, windmills, towers etc exhibit the same responses as confined conductors. Due to their very high electrical conductivity, they usually show very strong responses across the whole decay-time range but, they are spatially confined, i.e. they have small spatial extent. Long linear cultural conductors, such as powerlines, railway lines, pipe lines and fence lines produce strong linear responses across all the survey lines affected. The powerline monitor (PLM) data (when available) displayed on the linear pseudosections will identify anomalies due to mains power (50Hz) electrical interference.

12. It is essential that the targeted TargetTEM™ responses be integrated with all available geological, geophysical and geochemical data in order to assess their geological significance as exploration targets.

13. Note that airborne EM systems cannot, in general, precisely locate a conductor as the conductor producing the measured response maybe located off-line (to one side of the survey line) and not directly below the EM system. Appropriately designed ground EM surveys are capable of accurately locating and defining a targeted conductor.

5 Comments on the survey data

1. IP effect:
   The induced polarisation (IP) effects appear in the 'BZ' and 'dBdtZ' line pseudosections as yellow zones where these reverse flowing currents cause the measured response to be negative at late times. They are shown for the full survey area in the IPlevel image (from the BZ data as this provides the best overall resolution), and the bipole plan images. Numerous induced polarisation effect anomalies occur throughout all survey blocks. In the pseudosections it is clear that the IP -effect is obliterating the EM induction response at mid to late times, which reduces the resolution of conductive responses. Some of these IP-effect response maybe related to polarisable, conductive sulphide bodies, others may be due to black shales, clays, swamps etc. See Section 2.6, and Appendices 2.6 and 4.4 for details of IP effect.

2. 'dBdtZ' and 'BZ' data:
   Note that the 'BZ' data produce better overall resolution than the dBdtZ data, so these alone can be used for integration with other data types and analysis of the data.

   The EARLY-time response shows that thin conductive overburden (blue zones) covers all of the north-eastern (Block 5.2), the eastern (Block 4 - Thomas Creek) and the southern part of Block 1. The red zones are likely to be related to conductive formational rock units or conductive weathered zones associated with formational features or structures, or water-filled creeks. Some of the red-zone responses maybe related to conductive sulphide bodies. Number of the blue zones in the EARLY and MID time data are related to IP-effect, causing the decay to steepen and become faster, i.e. due to the effects of the reverse flowing IP-effect currents, which are shown as yellow when the MID to LATE-time measured response becomes negative. The induced polarisation (IP) effects can be clearly seen in the line pseudosections as yellow zones, and shown for the full survey area in the IPlevel image.

3. 'CZ' response:
   There are many anomalous 'CZ' decays in the survey area extending over the full time range, and many extending only from mid times, that warrant investigation. Some of these appear to relate to conductive formational features, i.e. rock formations, contacts, shear zones, faults and water-filled creeks. At late delay times the 'CZ' response is noisier due to lower signal strength and the contribution of IP-effects.

   A number of anomalous EM responses in the various 'CZ' ranking images either coincide with 'bright spots' in the TMIHP image, or groups of these anomalies cluster around various TMIHP anomalies. The EM data need to be integrated with the high-pass filtered magnetics, IP-effect and DTM data to accurately identify correlations, particularly EM responses that maybe related to terrain variations. Coincident EM and IP responses maybe important exploration targets.

4. 'dBdtZ_RR' and 'BZ_RR' (regional removed) responses:
   There are many anomalous decays in the survey area extending over the full time range, and many extending only from mid times, that warrant investigation. Some of these appear to relate to conductive formational features, i.e. rock formations, contacts, shear zones, faults and water-filled creeks. At late delay times the 'CZ' response is noisier due to lower signal strength and the contribution of IP-effects.

   A number of anomalous responses in the various 'dBdtZ' and 'BZ' ranking images either coincide with 'bright spots' in the TMIHP image, or groups of these anomalies cluster around various TMIHP anomalies. The EM data need to be integrated with the high-pass filtered magnetics and DTM data to accurately identify correlations, particularly EM responses that maybe related to terrain variations.

5. Magnetics:
   A number of anomalous responses in the various 'CZ' ranking images either coincide with 'bright spots' in the high-pass filtered (regional removed) total magnetic intensity (TMIHP) image, or groups of these anomalies cluster around various TMIHP anomalies. The EM data need to be integrated with the high-pass filtered magnetics and DTM data to accurately identify correlations, particularly EM responses that maybe related to terrain variations.

6. Powerline interference
   See the ‘powerline’ image and the powerline monitor (PLM) channel displayed in the line pseudosections. The powerline monitor data show no evidence of 50 Hertz powerline interference.

7. The Thomas Creek area (Block 4) covers a strong and complex magnetic anomaly. The high-pass filtered magnetic data resolve detail in magnetic structure of the area. LATE-time IP-effect is extensive over the central area. Consequently, most of the ‘BZ’ EARLY to MID-time responses appear as blue zones rather than conductive red zones. This suggests a polarisable conducive source located in the central area of the magnetic complex, which is resolved as a magnetic ‘low’ in the high-pass filtered data.

8. Note that it is not possible to quantitatively analyse or model EM responses affected by IP-effect with conventional conductivity-depth-imaging (CDI) or layered-earth (LE) techniques.

6 Recommendations

1. Follow the instructions given in Section 4.2 for using the various processing products.

2. It is recommended that plans of the TargetTEM^{TM} EARLY, MID and LATE-time channels be integrated with other geophysical, geological and DTM data, the IP-effect plan image and the anomaly ranking ranking (RK) plans, in order to target conductors for further investigation and to access the geological significance of the targeted conductors. Note that the 'BZ' data provide better overall resolution of the results than the 'dBdtZ' data.

3. It is recommended that the induced polarisation (IP) effects plan image be integrated with the high-pass filtered magnetics and other geophysical, geological and DTM data to access the geological significance of the various IP-effect anomalies.

4. Note that where the survey line spacing is wide relative to the size of target being sought, then single line anomalies maybe be important exploration targets.

5. It is recommended that ground EM surveys be conducted to further investigate the targeted TargetTEM^{TM} conductors. Ground EM surveys have higher sensitivity than airborne systems and can be designed to accurately locate the targeted conductor and to accurately determine its spatial extent. They can also provide temporal response data (decay measurements) to later delay times than is obtainable with airborne EM systems.

6. It is recommended that, for targeted conductors having associated strong IP-effect responses, consideration be given to investigating these polarisable conductors with ground resistivity-IP surveys rather than an EM surveys, because the IP response could be stronger than the inductive EM response and provide greater spatial resolution of the anomalous source.

Appendix 1. TD-AEM measurements

A1.1 General

Airborne EM is a complex science involving a variety of data types in several measurement directions (components) for a large number of data channels. Most types of time domain airborne EM (TD-AEM) systems, such as GEOTEM, MEGATEM, TEMPEST, SPECTREM, HeliTEM, VTEM, Xcite, XTEM, SkyTEM and AeroTEM transmit a pulse waveform, or a continuous series of pulses. The decaying secondary magnetic field (the B-field) is measured with a coil sensor, which is actually sensitive to the time-rate of change of the magnetic (B) field, i.e. in physics parlance it measures dB/dt. From the dB/dt measurements the actual strength of the field can be computed at each decay time to produce B-field data. Measurements are made at a number of delay times (Fig. 1b) to record the decaying secondary field.

A1.2 STEP and IMPULSE responses

From the dB/dt and B-field data, two types of ground responses can be obtained: the STEP response and the IMPULSE response, in both the X- and Z-components (see Appendix 1.3). The STEP response is the response of the ground to an abrupt or step-like turn-off of the primary field (Fig.2). This is sensitive to conductors over a wide range of conductivity and size, in particular, to the slow-decaying conductors with very high conductivity and large size. These are referred to as good quality conductors.

The IMPULSE response is the response of the ground to a sudden instantaneous pulse or 'spike' change in the primary field. It can be obtained by using a coil receiver to measure the response produced by the step-like turn-off of the primary field. It is only sensitive to the fast-decaying conductors with low to moderate conductivity or small size, i.e. poor quality conductors. It is insensitive to conductors with high conductivity and large size, but it produces a stronger response to poor conductors than the STEP response. The IMPULSE response complements the STEP response in detecting a wide range of conductive bodies.

For most TD-AEM systems, the dB/dt data are the IMPULSE response and the B-field data are the STEP response (they actually approximate the respective responses and depend on the shape of the transmitted primary field pulse). The SPECTREM and the TEMPEST systems produce only STEP response and not IMPULSE response data. For the AeroTEM system, the ON-time data are the STEP response and the OFF-time data are the IMPULSE response.

TargetTEM™ can be applied to both the STEP response and IMPULSE response data. The interpreter must appreciate that good conductors maybe indicative of salinity and weathering effects, and that many electrically-conductive ore deposits exhibit poor conductivity, so identification of poor conductors is as important as identifying very good conductors.

See Dentith and Mudge (2014) for detailed descriptions of the impulse and step responses.

A1.3 X and Z components

The geometry and attitude of the conductor with respect to the EM system determines the amount of energy coupled into the body. It is quite possible for a body of high conductivity to couple poorly with the EM system because of poor target-system geometry, so that it produces a poor response or, at worse, no response at all. Measurement of both the along-line (X), the across-line (Y) and vertical (Z) components helps enormously in detecting a response for a wide range of target-system geometry; because it is possible to measure a strong response in one component and a small response in the others. This is done by making the measurements with several coils whose axes are oriented perpendicular to each other, i.e. one horizontal in the along-line direction (X-component) and the other vertical (Z-component). The vector components of the decaying secondary magnetic field provide information about the geometry of the sub-surface conductor. Most modern TD-AEM systems make B-field and dB/dt measurements in both the X- and Z-components. The Y-component contains less information and is not routinely measured.

In fixed-wing systems the receiver coils are towed outside the transmitter loop, they are geometrically asymmetric systems so the measured anomaly has a complex shape. For helicopter systems the receiver coils are coincident with the transmitter loop, they are geometrically symmetrical systems and produce simple anomaly shapes.

X- and Z-component data will respond differently to conductors of various geometry, and can be quite different for asymmetric and symmetric systems. It is beyond the scope of this report to provide details of the wide range of anomaly shapes possible for the various systems. Generally, the Z-component will provide better vertical resolution and the X-component better lateral resolution. Dentith and Mudge (2014) give detailed descriptions of the various component measurements and their anomaly shapes for the various loop arrays. Also, survey logistics reports supplied by the survey contractors often include an atlas of anomaly responses for a range of common simple-shaped conductors (e.g. sphere, thin dipping plate, horizontal plate, thick tabular body, multiple dipping plates, conductor below a conductive horizontal layer etc.).

Note that for the case when the receiver is located at the centre of the transmitter loop (in-loop array), as is the case for all the helicopter TD-AEM systems, there is no horizontal (X) component response from a conductive horizontal layer and the conductive background; i.e. the in-loop X-component is insensitive to these conductivity structures. Consequently, only the vertical (Z) component data can be used for LEI and CDI computations. However, this also means that the in-loop X-component is sensitive only to lateral changes in conductivity and the responses of confined conductors, even when they are located below conductive overburden or in conductive host rocks. The in-loop X-component is the component of choice when exploring for confined conductors, and particularly in conductive environments.

A1.4 Powerline interference

Most airborne EM system include a powerline monitor channel that measures the level of powerline 50/60Hertz electrical radiation at each survey location. This is a reliable indicator of the presence of powerlines in the survey area, which respond strongly and are a common source of interference to the EM measurements. Also, the power distribution system uses the Earth as a return circuit and these transmitted earth currents can be detected by the EM system's powerline monitor, particularly in high conductivity environments which provide an easy path for the current flow. Also, survey height often changes abruptly (see Section 2.5) as the aircraft climbs higher to pass over the powerline.

Appendix 2. TargetTEM^{TM} computed responses

A2.1 COMPOSITE response

For the convenience of displaying and analysing the large volume of data available from airborne EM systems that produce both STEP and IMPULSE response measurements (see Appendix 1.2), the TargetTEM^{TM} regional-removed STEP and IMPULSE responses are merged to form the COMPOSITE ('C') response. The COMPOSITE response is a very effective way of presenting both the IMPULSE and STEP responses in a single image and is ideal for targeting compact or confined conductors, but <u>not</u> conductive layers of large spatial extent.

The COMPOSITE response is a graphical presentation of the STEP and IMPULSE responses; being the strongest of the two responses at each data point. It can only be displayed with the dual-polarity bipole plot presentation (see Appendix 3.1). Only the positive values of both the dB/dt and B-field (or the AeroTEM ON-time and OFF-time measurements, respectively) regional-removed (RR) data are used to produce the COMPOSITE bipole plots.

In the COMPOSITE response data files ('**_CZ_RR.dat*' or '**_CX_RR.dat*'), the IMPULSE response values are flagged as negative values and the STEP response values are flagged as positive values. In the bipole plots (see Appendix 3.1), the COMPOSITE response of the Z-component data is plotted in magenta and that of the X-component data in red.

Note that the COMPOSITE (C) response is inappropriate for AeroTEM data due to the different delay times used for the ON- and OFF-time measurements.

A2.2 TOTAL response

For the convenience of displaying and analysing the large volume of data available from TEM systems that produce only the STEP or the IMPULSE response (see Appendix 1.2) in both X- and Z-component data (see Appendix 1.3), the TargetTEM^{TM} processed X- and Z-component data are merged to form the TOTAL ('T') response ('**_dBdtT_RR.dat*' or '**_BT_RR.dat*'). It is a graphical presentation of the X- and Z-component responses; being the strongest of the two responses at each data point. It can only be displayed with the dual-polarity bipole plot presentation (see Appendix 3.1). Only the positive values of both the X- and Z-component regional-removed (RR) data are used to produce the TOTAL bipole plots.

The TOTAL response values are plotted in magenta and represent zones of higher conductivity. The TOTAL response is a very effective way of presenting both the X- and Z-component responses in a single image. Note that the TOTAL response is not appropriate for in-loop X-component data, i.e. all the helicopter EM systems.

A2.3 EARLY-, MID- and LATE-time responses

The TargetTEM^{TM} responses are computed for each decay channel of the EM system. The multichannel response are then compressed into three (3) channels; the EARLY-, MID- and LATE-time (EL) responses, for the COMPOSITE response in both the X- and Z-components, and for the TOTAL response. They are a convenient way of reducing the large number of channels into more practical fewer channels. The EARLY response is calculated from the earlier time channels, the various MID-time channels from later groups of channels, and the LATE response from the remaining late-time channels.

The actual system channels compressed into each of the TargetTEM^{TM} 'EL' responses are specified in the TargetTEM^{TM} line data description files (*.des) along with the channel mid-times, and also displayed at the end of this report in the section 'System Decay Channels'. The three compressed 'EL' channel responses are presented as bipole plan plots. The three 'EL' channels of the regional-removed ('RR') data are used to rank the TargetTEM^{TM} responses (see Appendix 2.5).

A2.4 EM-anomalies response

TargetTEM™ further compresses all the regional-removed (RR) EARLY-, MID- and LATE-time (EL) channel responses into a single response referred to as the EM-anomalies (EManoms) response. This reduces the large number of channels into a single channel response and is a convenient way of displaying the lateral extent of all the anomalous conductivity zones. The EManoms response is presented as a bipole plan plot in a single colour, the same as that used for the COMPOSITE and TOTAL responses. Greater resolution of the responses can be obtained from the individual EARLY-, MID- and LATE-time (EL) responses (see Appendix 2.3).

A2.5 Anomaly ranking

In order to assist in quickly identifying target responses in the, often, large number of conductivity variations resolved by TargetTEM™, the computed regional-removed (RR) EARLY-MID-LATE -time responses (see Appendix 2.3) are ranked, or prioritised, according to their histogram/frequency distribution and the last channel that the response was detected. Ranking (RK) is applied to the histogram distribution of each of the EARLY, LATE and MID time channels; of either the COMPOSITE (C) response data (see Appendix 2.1) when available, or the TOTAL (T) response data (see Appendix 2.2) when available. Otherwise, ranking is applied to the regional-removed (RR) B-field (STEP response) and/or the dB/dt (IMPULSE response) data.

Ranking is based on the histogram/frequency distribution of the data in each of the EL channels. Higher level class intervals of the distribution indicate longer decays or better conductors.

Ranking detects a selected percentage class range in the histogram/frequency distribution in each of the three (3) EL channels, identified by rank ranging from 1 to 3, depending on the latest channel that the response extends to. Rank 3 (highest ranking) indicates that the decay extends to the LATE time channel and falls within the selected histogram/frequency distribution range; rank 2 indicating that the decay in the selected class range only extended to the MID-time channel and rank 1 indicating that this decay in the selected class range did not extend beyond the EARLY time channel. A rank value of zero indicates that the amplitude of the TargetTEM™ response does not reach the selected histogram/frequency distribution level for any of the three channels. Clearly then, good quality conductors with a slow decay will have ranking 3 and poorer quality conductors with faster decay could score a ranking of only 1.

Three (3) pen colours are used to depict the ranking level as follows: blue (1, EARLY-time), green (2, MID-time) and red (3, LATE-time); good quality conductors would extend to rank 3 (red zones) and poor conductors would have rank 1 (blue zones).

For the plan plots, all the pen strokes have the same height clipped to the approximately half the survey line spacing, and the colour palette is displayed in the bottom right-hand corner of the plot. They can be overlain on the various bipole plan plots, such as the EARLY, MID, LATE and the EManoms responses, and the greyscale images of magnetics, DTM and survey height to quickly identify target zones for further investigation. LATE-time channels are often noisy due to the very low signal strength, so good conductors can often also be more reliably identified as green (rank 2, MID-time channel) zones. Plan plots showing the survey lines and the pseudosection lines are also provided and these can be overlayed on any of the other plan plots to identify individual survey lines and pseudosection lines.

Ranking is done using two ways of specifying the ranking class range in the histogram/frequency distribution of the data in each EL channel. Either as a selected top-level of the distribution in each EL channel or as a selected interval of the class distribution.

A2.5.1 Top-level ranking

The data are ranked for seven (7) selected top percentage-levels, usually the top 1%, 2%, 3%, 4%, 5%, 7%, and 10% levels in each of the EL channels. A ranking level of 1% selects the top 1% of the total number of data points in each of the three EL channels and, for each data location, ascribes a rank to the decay according to latest channel that the selected level of the measured decay appears in. So the top 1% of data in the LATE channel are ascribed a rank of 3, but if the decay was shorter-lived extending to, say, the MID-time channel, then it will be ascribed a rank of 2, and so on with rank 1 being the shortest-lived EARLY time channel data.

Increasing the top-level ranking selection level includes more histogram classes (increases the number of data points) in the three channels for ranking. This generally widens 'anomalous' zones detected at lower levels and produces more 'anomalous' zones and, consequently, lowers the resolution of the best responses in each of the three EL channels. Displaying the individual regional-removed (RR) EARLY-MID-LATE -time response plan plots is the same as selecting the full amplitude range (being ranking level of 100% - every data point) of each response.

In addition to plan plots, the top-level rankings are also displayed as pseudosection overlay plots that fit the LINEAR pseudosection plots (see Appendix 3.1) for each survey line. They display the seven (7) top-level ranking levels in the profile plotting area of the LINEAR pseudosections. Annotations at each end of the pseudosection display the actual ranking percentage levels. The decay channel names displayed at each end of the LINEAR pseudosections are also colour coded to highlight their allocations to the EARLY, MID and LATE-time channels. The colours are the same as those used in the ranking scheme, i.e. blue for the EARLY-time channels, green for the MID-time channel and red for the LATE-time channel. This makes it very easy to relate the ranking zones with their respective EARLY-MID-LATE channel.

Note that <u>higher</u> classes in the histogram/frequency distribution are longer decays (better conductors). Ranking then indicates relatively poor to good quality within the selected top-level class of conductor. Only the highest quality conductors in the full dataset appear in the highest top-level ranking (1%); lesser quality conductors will be included in lower level top-level selections.

The top-level ranking data are displayed as bipole type plan plots (**_tmRankTop%%_pln.dxf*), one for each percentage level, and as LINEAR pseudosection overlays for each survey line (**_tmRK_lin.dxf*) displaying all seven (7) percentage levels.

A2.5.2 Selected-interval ranking

The data are ranked for a selected range of histogram class intervals specified by the minimum and maximum percentage levels for that range and provides a more thorough analysis of the full data set.. Typically, the interval is chosen as 10% to produce ten (10) ranking plot files (across the full range of 100%), noting that the range 90%-100% (identified as 90-00 in the file name) is the same as the top-level rank of 10%. The smallest useful interval range is 5% and that would produce twenty (20) ranking plot files.

For example, a ranking interval level of 20% to <30% (identified as 20-29 in the file name) selects the 20 percent to less than 30 percent interval of the histogram/frequency distribution of the three EL channels and, for each data location, ascribes a rank to the decay according to latest channel that the selected level of the measured decay appears in. So the 20-30% interval data in the LATE channel are ascribed a rank of 3, but if the decay was shorter-lived extending to, say, the MID-time channel, then it will be ascribed a rank of 2, and so on with rank 1 being the shortest-lived EARLY time channel data.

Note that <u>higher</u> classes in the histogram/frequency distribution are longer decays (better conductors), so selected intervals <u>lower</u> in the range relate to poorer quality classes of conductors. Ranking then indicates relatively poor to good quality within the selected class of conductor.

The selected-level ranking data are displayed as bipole type plan plots (**_tmRank%%-%%_pln.dxf*), one for each percentage interval.

A2.5.3 General

Note that some economic minerals are electrical insulators, for example sphalerite; and that disseminated mineralisation and mineral grain-boundary conditions strongly determine electrical connectivity and can reduce the overall conductivity of a mineral deposit. The various TargetTEM™ responses need to be integrated with geological information and other geophysical data in order to assess the geological significance of the computed responses. Variations in survey height can sometimes affect the TEM decay, which may produce correspondingly small variations in the rank level.

It is important to be aware that the TargetTEM™ ranking is not an indicator of the economic significance of the EM response of a conductor nor is it an indicator of its geological significance.

A2.6 IP level

Negative polarity decay values are generally accepted as being due to the reverse current flow of the induced polarisation (IP) response of the ground, and usually seen at later decay times when the induced EM currents have diminished in intensity (see Section 2.6). TargetTEM™ flags the negative polarity channels only from the unfiltered Z-component data. These are displayed in the pseudosection plots in yellow (not displayed in the regionally-removed data plots '_RR').

To show the spatial distribution of the IP-effect, the area of the negative part of the decay curve is used as a proxy for the intensity of the IP-effect, i.e. a larger area is taken as stronger IP-effect than a smaller area. For each channel, the area is the channel width in milliseconds multiplied by the channel amplitude, and these are summed for all the negative polarity channels in the decay. The units being the channel amplitude units multiplied by time (ms). If no channel is negative-valued, the IP-effect is taken as zero. The IP-effect is displayed in a monocoloured bipole plan as the IPlevel (see Appendix 4.3).

Appendix 3. TargetTEM™ products

A3.1 Bipole plots

The bipole, or bipolarity, images are a highly effective means of accurately displaying every data point in a line data set that has a base level value of zero. Each data (sampling) point is depicted with a single plotted line, or pen stroke, oriented perpendicular to the local direction of the survey line. The amplitude of the data value is depicted by the length of the pen stroke and clipped to the survey line spacing to prevent over-plotting onto the neighbouring survey lines. The colour of the plotted line depicts the polarity (sign) of the data value, so it is a bi-polarity display. For the raw survey data, positive values are displayed in red and negative values in blue and, where IP-effect is detected, it is plotted in yellow. For the regional-removed (RR) data, the vertical Z-component data are displayed in magenta and the along-line horizontal X-component data are displayed in red. Zero values and missing data points are plotted with a small black line. See Appendix 3.2 for details of GIS software suitable for accurately displaying the bipole plot files (these are AutoCAD *.dxf format files).

Bipole plots are free of distortions caused by the gridding algorithms used to make bitmap images; they present every data point on the survey line and maximise resolution of the line data. In particular, their resolution is independent of the survey line spacing, unlike gridded data where wider line spacing reduces image resolution. Bipole plan plots can be overlain on bitmap images and are a very effective way of integrating the various responses.

TargetTEM™ responses have negative and positive values about a base level value of zero so bipole plots are the ideal technique for displaying the data. Also, many airborne EM surveys are conducted on widely spaced survey lines, compared to the very close along-line data interval, rendering grid and image presentation techniques unsuitable. TargetTEM™ responses are displayed as bipole plan plots for each of the EARLY-MID-LATE channels, and as survey-line pseudosections.

Bipole plots are prepared as PLANS of each of the compressed EARLY-, MID- and LATE- time channels and are useful for displaying the spatial extent of the response of the various channels across the survey area. Plan plots showing the survey lines and the pseudosection lines are also provided and these can be overlayed on any of the other plan plots to identify individual survey lines and pseudosection lines.

Bipole plots are also prepared as PSEUDOSECTIONS of each survey line showing all the decay channels. The PSEUDOSECTIONS display the computed parameters plotted against channel number and channel decay mid-time increasing downward and are useful for showing the response across all the channels along the survey line. The time-based decay channels are given equally-spaced false depths to position them on the pseudosection. The bipole PSEUDOSECTION plots are NOT depth-sections, they are pseudo-time sections using channel number as a proxy for delay time. There are three types of bipole PSEUDOSECTION images.

The LINEAR_PSEUDOSECTION images (*_lin.dxf*) display the survey data projected onto a straight line (the pseudosection line) and plotted as linear distance along the length of the survey line in local grid co-cordinates. Profiles of survey height above the terrain, terrain data (DTM), magnetics and the high-pass filtered magnetics are shown positioned above the bipole channel plots. The DTM data are plotted in black and the survey height in blue. The magnetic data are plotted in red with the full amplitude range of the data fitted into the vertical size of the profile plot. The magnetics are high-pass filtered to remove the regional magnetic response and to resolve weaker amplitude, shorter wavelength features. The high-pass filtered data are plotted in magenta with vertical scale optimised for each survey line. The powerline monitor (PLM) data are plotted in black as a histogram line-profile along the baseline of the profile plotting block.

The linear pseudosections are fully annotated: along-line distance measured from the left-hand end of the pseudosection is depicted with 100-metre ticks and annotated every 1,000 metres along with the real-world co-ordinates; the channel names with their mid-channel delay time in microseconds are displayed at both ends of the pseudosection and colour coded to their corresponding EARLY, MID or LATE-time channel allocation (blue for the EARLY-time, green for the MID-time and red for the LATE-time channel); the survey line number and survey direction arrows are also displayed at both ends of the pseudosection, and also at the middle-distance of the pseudosection. The linear pseudosections are the only images that display the DTM, height, magnetics and powerline signal with the multichannel

TargetTEM™ data in a single image. The RANKing overlay plots (see Appendix 2.5) for each survey line are designed to be viewed on the linear pseudosections, to display the six (6) percentage levels of ranking along the survey line. Also, the real-world co-ordinates for every 100-metre tick are displayed in the line co-ordinate text file associated with each pseudosection (‘*_tmCH_lin_xen.txt*’). A plan plot showing the pseudosection lines is also provided and can be overlayed on any of the other plan plots to identify individual pseudosection lines.

The 3DLOCATED_PSEUDOSECTION images (*_loc.dxf*) display the pseudosection in real-world 3D co-ordinates. In section view, the survey line trace (shown as a black line) delineates the DTM variations and in plan view the survey line path. These plots can only be displayed using a GIS viewer capable of displaying 3D co-ordinated data. They can be integrated with any type of section/depth data. There is no text information in these plots. The 3D located pesudosections are an optional processing product that can be provided if requested.

The ROTATED_PSEUDOSECTION images (*_rot.dxf*) are the 3DLOCATED_PSEUDOSECTIONs rotated onto the horizontal plane and located in real-world co-ordinates (they are a plan view of the pseudosections). They fit the actual survey line trace and can be displayed with a conventional 2D GIS viewer. Note that the actual location of a feature in the rotated pseudosection is on the survey line (shown as a black line) `and not at the plotted location. The survey LINE plot can be overlain on them and they can be plotted over any other 2D image. There is no text information in these plots. The rotated pesudosections are an optional processing product that can be provided if requested.

Note that all pseudosection plots are oriented so that the real-world horizontal locations increase from left to right on the plot; so generally east-west oriented survey lines will increase in easting to the right, and generally north-south oriented survey lines will increase in northing from left to right.

A colour palette is displayed in the bottom left-hand corner of each bipole channel PLAN plot and LINEAR_PSEUDOSECTION plot to confirm that the correct colours are being mapped to the plotting pens in the GIS software. The correct colours for the LINEAR_PSEUDOSECTIONs in order from left to right are BLACK, BLUE, MAGENTA or RED, followed by YELLOW; and for PLANs it is BLUE and RED. For regional-removed (RR) data it will be either MAGENTA or CYAN; and YELLOW for IP-effect. <u>It is essential that these pens have the correct colours as these are fundamental to the analysis of the bipole plots</u>. See the text file ‘*_TargetTEM_images.rtf*’ for details of the colour palette and the pen colours. If required, refer to the viewer/software instructions for changing the colour mappings of the plotting pens (if possible).

The survey LINE plot displays the survey lines with their line numbers plotted at the start of each line. The LINE plot can be overlain on any of the channel PLAN images and the gridded bitmap images to display the line numbers, essential for identifying a survey line for displaying its pseudosection plot.

A3.2 Bipole plot display software

Bipole plots are produced as AutoCAD vector drawing *.dxf formatted files as this format is the most commonly used for vector graphics. Note that some GIS software (intentionally) won’t display vector graphics files accurately (mis-located text, erroneous line thickness, incorrect pen colours etc).

The popular GIS software TatukGIS-Editor and TatukGIS-Viewer accurately display the bipole *.dxf plot files produced by TargetTEM™ and can also display and integrate a large range of other graphics file formats, and is very easy to use (available on line as an evaluation product, the Viewer is $free, from www.TatukGIS.com). The TatukGIS-Editor can also display 3D (*_loc.dxf*) plot files to display a data volume of parallel survey line located pseduosections produced by TargetTEM™.

Note that the axes of the pseudosection plots are in terms of linear horizontal distance versus vertical distance, and that the dimensions of the plan plots are (real world) horizontal distances in both axes. As a consequence of the different axes dimensions, it is not possible to view both a pseudosection and a plan plot together in the GIS software, so it will be necessary to have two sessions of the GIS software operating in order to display both types of plots simultaneously.

A3.3 XYZ data

Optionally, TargetTEM™ data can be viewed as a 3D data-volume using the XYZ-data provided in the formatted files (**.xyz*) located in the file directory '**>XYZData**' (when requested). The channel values are scaled as for the PSEUDOSECTION bipole plots; they are the height of the pen strokes on the pseudosection assuming that the channels are spaced 100 metres vertically, and without amplitude clipping. Each channel value is written to the file as a single located record and is given a false relative level (false depth) to locate it vertically in the data volume. In this format, the data can be treated like other point-located data types, such a downhole geochemical assays. The channels are vertically spaced 25 metres apart, approximately two to five times the typical along-line data interval, and increase negative downward as a false RL. Note that **the channels are time-based and do <u>NOT</u> represent depth.** The XYZ located data file can be read by any software system capable of displaying the data as a 3D data volume. Height, DTM and magnetics are not included in the records. Details of the file format are given in the associated XYZ-data header file (**.hdr*).

When displaying the 3D data-volume, note that negative channel values may be rejected by some 3-dimensional display systems as erroneous (a negative assay value being considered improbable). In this case, the channel values can be offset at the time of importing the data into the 3D display software, to eliminate negative values by adding the offset value given in the associated XYZ-data header file (**.hdr*).

Appendix 4. TargetTEM™ conductor responses

A4.1 Geological conductors

See Dentith and Mudge (2014) for descriptions of the TEM responses of the various classes of conductors common to the geological environment. In summary, the main geological features that influence the TEM responses are conductive layers, conductive host rocks (essentially a very thick layer), and confined conductors of low and high conductivity and size, i.e. poor and good quality conductors, respectively. The following summarises the important characteristics of the responses of each class of conductor:

- A conductive thinner layer, such as conductive overburden, has the fastest transient decay (shortest decay time) and appears in the early decay times as blue in the bipole plots. This depends on the minimum and maximum measurement times of the EM system being used, but the faster decaying signal will have disappeared by the late measurement times of most systems. Note that the conductive layer response does not appear in in-loop X-component data (data from helicopter systems).

- A conductive thicker layer and the host rock response have slower decay and will persist to later measurement times and will appear as red in the bipole plots. Note that the conductive layer response does not appear in in-loop X-component data (data from helicopter systems).

- Near surface (paleo-) channels usually respond as conductive layers.

- Confined conductors have slower decay (longer decay time) than conductive layers (e.g. overburden) and the host rock response, and will appear as large amplitude red in the bipole plots. Bodies of very high conductance (very good quality conductors) have the slowest decays (longest decay times) and can usually be detected to very late times (Fig. 2). However, they are often only seen in the B-field (STEP) response data, and not the dB/dt (IMPULSE) response.

- For confined conductors, decay time relates mainly to their conductivity and size, i.e. their quality, and not their depth. When there is no conductive overburden or significant background responses present, the response of a confined conductor will be seen at all decay times as red – the ideal situation. Note that bodies with very high conductivity (very high quality conductors) will only be seen in the B-field (STEP) response, and not the dB/dt (IMPULSE) response (Fig. 2). The response of highly conductive bodies, such as massive sulphides, and in particular nickel massive sulphides, will only be detected in the STEP responses, and not the IMPULSE responses. On the other hand, conductors of low conductivity produce stronger responses in the IMPULSE response than the STEP response.

- Note that sometimes a geological body may show conductivity zoning, where one region of it maybe more conductive and another region more resistive. In this case it is likely that several EM anomalies may be identified, each associated with the separate current systems induced in the various conductivity zones. It is likely that the responses may be distributed between the IMPULSE (dB/dt) and STEP (B-field) response data.

- Very large steeply dipping conductors, such as rock formations and structures, can respond as unconfined conductors allowing their eddy current system to decay rapidly with power-law response. In addition, they may be galvanically connected to the conductive background rocks and the overburden causing currents to be channelled into them and to expand and decay rapidly. This effect is referred to as current gathering or current channelling (see Section 2.4 and Appendix A4.3) and usually appears as a 'blue' zone in the TargetTEM™ resposnes.

A4.2 Conductive overburden

The presence of highly conductive overburden has a significant effect on the response and detectability of a deep confined conductor as the overburden response will obliterate the conductor response at early decay times. The slower decaying response of the confined conductor will be seen at later decay times after the faster decaying response of the overburden and background have diminished. Note that the conductive layer and background responses do not appear in in-loop X-component data (data from helicopter systems), so the response of a confined conductor can be expected to be resolved in the early time channels of the X-component.

A4.3 Other conductivity responses

Galvanic connection between a confined basement conductor and the conductive layers, such as an overburden layer, is likely to create galvanic current channelling; where currents flow between the confined conductor and the conductive host rocks and conductive overburden. It produces a very fast decay that strongly distorts the exponential decay of the confined conductor. The conductor response may be seen at later decay times after the current channelling has diminished. Current channelling is difficult to accurately detect, but very fast decays are removed in the TargetTEM™ regional-removed and COMPOSITE responses.

A4.4 Induced Polarisation responses

Anomalous EM responses can be produced by the induced polarisation (IP) of clays, carbonaceous shales and sulphide mineralisation. They can also be associated with the boundary between the base of a conductive overburden layer and a higher resistivity basement, the actual mineralogical source and electrical mechanism of the IP effect in these situations are not well understood. The resultant IP current flow is a discharge current, of the charge stored by the induced current, flowing in the reverse direction to the induced current. It flows in the horizontal plane of the boundary, so for an in-loop receiver, it will only be detected by the Z-component and not the X-component. When the receiver is located outside the transmitter loop, the IP-effect will be detected by both the Z- and X-component receivers.

The receiver measures the resultant field due to the vector addition of the responses from all individual conductors that couple with the receiver, and the slower decaying field of the IP current. The reverse-flow direction of the IP current has the effect of reducing the resultant signal measured by an in-loop Z-component receiver and 'pulls' the decay down, i.e. the measured decay is faster than if the IP current were absent. At some later decay time when the faster decaying induced eddy currents are weaker than the slower decaying IP current, the resultant response now being dominated by the IP current will change polarity and show the negative decay of the IP current. When the receiver is located outside and distant from the loop, the IP currents will have the same polarity as the induced currents causing the decay to be 'pulled up', i.e. producing as slower decay. For this case it is not possible to identify the presence of IP current.

IP effects are identified by the negative response they produce in the TEM data due to their reverse direction of their current circulation (Section 2.6 and Appendix 2.6). They are more reliably detected in Z-component measurements of helicopter systems data (where the receiver coil is coincident with the transmitter loop). They are displayed as yellow zones in the TargetTEM™ dBdtZ and BZ pseudosections, but not in the regional-removed ('RR') data. The IP level data are displayed as plan plots in yellow. In fixed-wing survey data, where the receiver being located outside the transmitter loop produces anomalous responses of both polarities, IP effects are more difficult to detect.

A4.5 Summary

For the unfiltered survey data:

- Background (overburden + host rock response) = zero; black in bipole plots.
- Thinner conductive layers = negative values; large lateral extent of blue in bipole plots.
- Thicker conductive layers = positive values; large lateral extent of red in bipole plots.
- Anomalous (confined) conductive zones = positive values; red in late times of bipole plots,
- Induced polarisation (IP) effects = yellow, when present, usually resolved in late times.

In the regional-removed data (RR):

- Background response has been removed = zero; black in bipole plots.
- Anomalous (confined) conductive zones in the COMPOSITE response = positive values; cyan for Z-component and magenta for X-component data in the bipole plots.

- Anomalous (confined) conductive zones in the TOTAL response = positive values; magenta in the bipole plots.
- In the EManoms plot, anomalous (confined) conductive zones = colour the same as the positive values of the COMPOSITE and TOTAL responses.
- The ranking (RK) plots show the latest time channels that the responses appear in.

Appendix 5. TargetTEM™ database

See Appendix 3.2 for details of GIS software suitable for accurately displaying the bipole plot files (these are AutoCAD *.dxf format files) and for displaying the imaged data.

The TargetTEM™ data and associated plot files are located in the following file directories, noting that all PLAN files carry the suffix "*_pln.dxf*":

1. **>BipolePlots_##_*(RR)*:** Holds the plan and pseudosection bipole plot files for the specified measurement component (##), and additionally for the associated regional-removed (***RR***) data. The sub-directories for all components, and for their regional-removed (RR) data, are as follows:

   >3DLocatedPseudosections: Plot files of the 3D-located bipole pseudosections of the survey lines (**_loc.dxf*).

   >LinearPseudosections: Plot files of the linear bipole pseudosections of the survey lines (**_lin.dxf*).

   >LinearPseudosections_EN: Text files of the horizontal X-axis co-ordinates (East, North) of the linear bipole pseudosections for the survey lines ('**_lin_xen.txt*').

   >RotatedPseudosections (optional): Plot files of the bipole pseudosections rotated to the horizontal and located to the survey lines (**_rot.dxf*).

   >Plans: Plot files showing the survey lines and the pseudosection lines; and the bipole plans for the compressed Early-Mid-Late channels and IPlevel (**_pln.dxf*).

2. **>BipolePlots_##_Ranking:** Holds the plan and pseudosection overlay bipole plot files for the ranking of the compressed Early-Mid-Late channels of the regional-removed (RR) data (see Appendix 2.5) for the specified measurement component (##). The sub-directories are as follows:

   >LinearPseudosections: Plot files of the linear pseudosection overlays of the survey lines displaying the seven (7) top-level percentage rankings for each survey line ('**_tmRK_lin.dxf*').

   >Plans: Plan plot files for each of the seven (7) top-level percentage rankings showing the three (3) rank levels plotted along the survey lines ('**_tmRankTop%%_pln.dxf*'); and similarly for each of the specified ranking intervals ('**_tmRank%%-%%_pln.dxf*'), where %% represents the percentage level.

3. **>Docs:** Holds the various text documents associated with the survey and the TargetTEM™ processing . See the text file '**_TargetTEM_images.rtf*' for details of the survey, EM system, images, file names and issues associated with displaying the bipole plot files. Details of the survey lines are contained in the TargetTEM™ line-list file '**_linelist.txt*'. This can be printed using MS NOTEPAD, but in order to fit an A4 page go to Format/Font and set the following parameters: Font="Fixedsys", Font style = "Regular" and Size=9, then click "OK".

4. **>Grids:** Holds the grids of DTM, survey height, magnetics (TMI), high-pass filtered magnetics (TMI-HP), the powerline monitor (PLM) channel and the central channels of the EARLY, MID and LATE -time channels. Images of these data are produced from these grids. Note that in airborne EM surveys ties lines are usually not acquired so it is not possible to micro-level the magnetic data; residual levelling errors are often seen in the imaged data. For surveys with very wide line spacing, it is usually not practical to produce grids of suitable resolution.

5. **>Images_colour:** Images of DTM, survey height, magnetics (TMI), the high-pass filtered magnetics (TMI-HP) and the powerline monitor (PLM) channel. Several colour images with different colour stretches, e.g. linear, histogram equalised and Gaussian colour stretches, maybe provided to improve the resolution of subtle features. Usually the Gaussian colour stretch provides the best overall resolution of the imaged responses, whereas the linear colour stretch shows the true amplitudes of the responses. Sun-illumination is usually applied to the images of

the magnetic data. Note that in airborne EM surveys ties lines are usually not acquired so it is not possible to micro-level the magnetic data; residual levelling errors are often seen in the data.

6. **>Images_greyscale:** Greyscale images are also provide as these are very effective as the underlying layer when displaying the multi-coloured ranking plots.

7. **>LineData:** Line data files of all the TargetTEM™ responses in standard ASEG-GDF format. It is this data that is displayed in the various plans and pseudosection plot files, and in the bitmap images. The EM system mid-channel times and the channel groupings for the compressed Early-Mid-Late channels are displayed in description files (**.des*) associated with each TargetTEM™ line data file, and are also displayed in the Appendices.

8. **>RawData:** The unprocessed data base files supplied by the survey contractor.

9. **>XYZData:** Holds the 3D data-volume XYZ-data line files (**.xyz*) (when requested).

Appendix 6. TargetTEM™ output files

TargetTEM™ produces a number of filtered responses from a single data file for each data type (dB/dt or B-field) and for each measurement component (Z-, X- and T-components). The located data files (*.dat) produced contain the **temporal** response for all channels and the EARLY-, MID- and LATE-time channels ("tmTT" file), and the RANKing and EManomaly data ("tmRK" file). Each located data file has a description file (*.des) associated with it which lists the survey parameters and describes the file format. A definition file (*.dfn) describing the data file record format is also produced. The description and definition files comply with the Australian Society of Exploration Geophysicists (ASEG) General Data Format revision 2 (ASEG-GDF2). The regional-removed data are identified with 'RR' in the data file name.

Example file names: "tmTT*abcd*_dBdtZ.dat" where "tm" indicates the temporal file, "TT" indicates TargetTEM data for all data channels and for EARLY-, MID- and LATE-time responses, and "*abcd*_dBdtZ" is the survey identifier. For the regional-removed data, "tmTT*abcd*_dBdtZ_RR.dat" and for the ranking and EM-anomalies data "tmRK*abcd*_dBdtZ_RR.dat"

Bipole plot files (*.dxf): Naming of these files includes the channel name for PLAN files, e.g. "tmEARLY" as the temporal response for the EARLY channel, and the survey line number for the PSEUDOSECTION files, e.g. "L1230" for survey line 1230.
Example file names: For channel plans: "*abcd*_dBdtZ_tmEARLY" and for pseudosections "*abcd*_dBdtZ_L1230_tmCH" where 'CH' indicates all the system decay channels are plotted. The PSEUDOSECTION files also carry a suffix identifying the type of pseudosection plot: "lin" for LINEAR pseudosections, "loc" for LOCATED pseudosections and "rot" for ROTATED pseudosections. All the various PLAN plot files carry the suffix "pln".

XYZ formatted files (*.xyz): TargetTEM™ responses are also presented in formatted XYZ data files to allow displaying as a 3D data volume. Each XYZ located data file (*.xyz) has a header file (*.hdr) associated with it which lists the survey parameters and describes the file format. The xyz located data files can be read by any software system capable of displaying the data as a 3D data volume.

Note: It is recommended that the file names and the contents of the various files NOT be changed.

References

Dentith, M.C. and Mudge S.T., 2014. *Geophysics for the Mineral Exploration Geoscientist*. Cambridge University Press. ISBN 978-0-521-80951-1.
A general text book on mineral geophysics giving non-mathematical explanations of theory and practice with example datasets from a wide variety of mineral deposit types. Section 5.7 describes airborne TEM systems.

Ley-Cooper, A. Y., Viezzoli, A., Guillemoteau, J., Vignoli, G., Macnae, J., Cox, L. and Munday, T., 2015. Airborne electromagnetic modelling options and their consequences in target definition: *Exploration Geophysics*, 46, 74-84.

Peters, G., Street, G., Kahimise, I. and Hutchins, D., 2015. Regional TEMPEST survey in north-west Namibia: *Exploration Geophysics*, 46, 37-35.

List of digital files

Survey name: Sorell, Tasmania.
Australia

****

SURVEY DATA:
Survey datum: GDA94, MGA Zone 55
Survey line data: a728_sorell_combined_vtem.dat and *.dfn
Type of data: VTEM 25Hz – dB/dt and B-field

****

TargetTEM™ FILTER RESPONSES (see description files (*.des and *.dfn) for file formats):
Notation for measurement type and field component:
dBdt = dB/dt data, B = B-field data, C = Composite response plot
Z = vertical (Z) component, X = along-line horizontal (X) component
Temporal response (all channels): tmTTsorell_vtem_#.dat
Rank and EM-anomalies: tmRKsorell_vtem_#.dat
where # = measurement type and field component

****

GRIDDED DATA:
Grid size: 40 metres
Grid type: inverse square distance with minimum curvature
Grid format: ER Mapper (*.ers)
Image format: bitmap (*.bmp, *.tab)

height = EM system survey height above ground level
dtm = digital terrain model, terrain height above sea level
tmi = total magnetic intensity
tmihp = high-pass filtered tmi
tmi_1vd = first vertical derivative of tmi
IPlevel = induced polarisation (IP) effect (dBdtZ)
PLM = powerline monitor
CHnn = raw signal amplitude for channel nn, usually the central channel of each of the compressed EARLY, MID and LATE-time channels.

BIPOLE plot files: AutoCAD (*.dxf)
tmEARLY = temporal response, EARLY-time
tmMID = temporal response, MID-time
tmLATE = temporal response, LATE-time
tmEManoms = anomalous EM conductivity zones
tmRankTop%% and tmRank%%-%% = ranking of the EARLY-, MID-, and LATE time channels where %% is the ranking percentage level; in red, green and blue.
IPlevel = IP level in yellow.

Lnnnnnn_tmCH_lin = temporal response, linear pseudosection, includes all channels, where 'Lnnnnnn' is the survey line number

LINE plot files: AutoCAD (*.dxf)
linelist.txt = text details of survey lines
survey_lines = edited survey lines
pseudosection_lines = linear_pseudosection lines with ticks at 1km (or closer) intervals

System decay channel times

As displayed in the TargetTEM™ line data description files (*.des) and on the line pseudosection plots:

VTEM channels

```
COMM>CHANNEL TIME-ZERO  (microseconds) =      0.0
COMM>CHANNEL#: MID-TIME (microseconds)
COMM>      13:    84     EARLY
COMM>      14:    97     EARLY
COMM>      15:   111     EARLY
COMM>      16:   127     EARLY
COMM>      17:   146     EARLY
COMM>      18:   168     EARLY
COMM>      19:   193     EARLY
COMM>      20:   221     EARLY
COMM>      21:   254     EARLY
COMM>      22:   292     EARLY
COMM>      23:   335     EARLY
COMM>      24:   385     EARLY
COMM>      25:   442     EARLY
COMM>      26:   508     EARLY
COMM>      27:   583     EARLY
COMM>      28:   670     EARLY
COMM>      29:   770     EARLY
COMM>      30:   884     MID
COMM>      31:  1016     MID
COMM>      32:  1167     MID
COMM>      33:  1340     MID
COMM>      34:  1539     MID
COMM>      35:  1769     MID
COMM>      36:  2032     MID
COMM>      37:  2334     MID
COMM>      38:  2680     MID
COMM>      39:  3079     MID
COMM>      40:  3537     MID
COMM>      41:  4061     MID
COMM>      42:  4664     LATE
COMM>      43:  5358     LATE
COMM>      44:  6155     LATE
COMM>      45:  7071     LATE
COMM>      46:  8123     LATE
COMM>      47:  9331     LATE
COMM>      48:10718     LATE
```