



THE AEROTEM^{HD} ADVANTAGE

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Abstract

AeroTEM is a helicopter time-domain electromagnetic system which is characterized by a rigid structure and by its ability to collect interpretable on-time data. These design factors facilitate effective surveying in any terrain for the acquisition of robust data sets.

The flexibility of a helicopter platform and the rigid nature of the structure which houses the transmitter and receiver make the system effective for surveying for a wide variety of purposes under virtually any terrain conditions.

The on-time dB/dt response decays extend the sensitivity of the system to highly conductive targets such as nickel and copper sulphides. These on-time data are provided as decays in both the X and Z components. The AeroTEM system also provides off-time data for the measurement of less conductive and more resistive geologic features.

Surveys in mineral exploration for metallic ores and for mapping programs attest to the general applicability of the AeroTEM system. Surveys completed for conventional and non-conventional petroleum exploration properties demonstrate the wide variety of uses that an HTEM survey with magnetics and radiometrics can provide.

Introduction

Since helicopter time domain electromagnetic (HTEM) systems commenced commercial surveys in the late 1990's they have become ubiquitous within the airborne geophysics community. The growth of airborne EM has seen the number of systems rise from less than 20 systems to well over 60 systems worldwide. Virtually all of this growth has been in the development of HTEM technologies. If the maturity of a technology is simply measured as a function of acceptance, HTEM is well on its way. However, it should be noted that the term HTEM represents a class of EM systems within which there exists a wide variety of systems, each with its own strengths.

The AeroTEM system was introduced in 1999 and subsequent developments have brought improvements in signal to noise and the introduction of on-time data. In the following, the characteristics that are unique to AeroTEM are discussed and survey examples are given.

Background

The AeroTEM system was developed in the mid-1990's and was first used in commercial production in 1999. The initial system had a 5 m diameter transmitter loop with 8 turns. The transmitted waveform was a bipolar, symmetric triangular pulse with a 40% duty cycle and a 150 Hz base frequency (Balch et al, 2002). The receivers, both X and Z components, were fixed together in the middle of the transmitter loop.

In 2004, work on the on-time data processing was completed and the same system produced on-time and off-time data sets for both the Z-component and X-component.



Figure 1: The First AeroTEM System

As part of the on-time development, full waveform streaming data is recorded for all surveys, providing backup and data surety. The on-time processing, is described further in the next section.

From 2004 to 2008, Aeroquest focused on improving the signal to noise of the AeroTEM system and increased the size of the system from 5 m to 12 m and now 20 m with the AeroTEM^{HD} system (Figure 2). The AeroTEM system digitizes the receiver signals on the EM bird and has GPS, altimeter and orientation instrumentation on the EM bird to provide more accurate positioning and orientation data for the EM system. The dipole moment ranges from 500,000 NIA to over

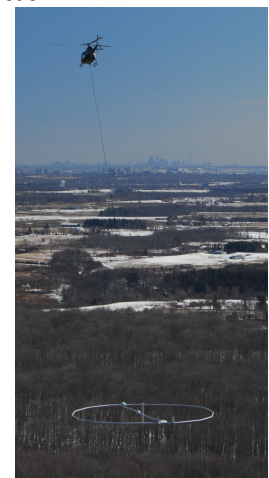


Figure 2: The AeroTEM^{HD} System in 2011

1,000,000 NIA, depending on the base frequency and configuration. This system provides both on-time and off-time data along with the raw stream data. The base frequency and duty cycle can be optimized depending on the application.

On- And Off-Time dB/dt Data

Most airborne EM systems offer a calculated B-field product which is provided to offer better sensitivity to highly conductive geology (Huang, 2007 and Smith, (2008) The combination of the system's rigid structure, triangular current pulse and streaming data make it possible to recover both usable early off-time and on-time data. The standard on-time data product from an AeroTEM system is a single decay derived through a primary field removal process involving a linear combination of the up- and down-slope on-time data. On- and off-time dB/dt nomograms forward modelled using a horizontal 100 m x 100 m plate buried at a depth of 50 m are displayed in Figure 3. The amplitude of the off-time response peaks at approximately 20 S and then decreases rapidly for high conductance targets. The on-time response, which peaks for a similar conductance value, decreases slower than the off-time response. The difference between these responses makes detection of targets with a conductance of over 10,000 S possible.

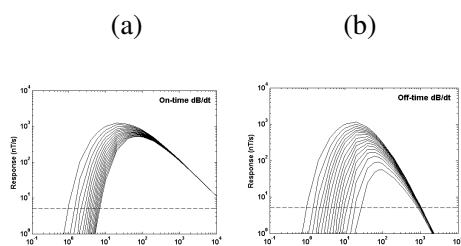


Figure 3: Nomograms calculated for an AeroTEM II system. (a) On-time dB/dt and (b) off-time dB/dt. Models generated using a 100 m x 100 m horizontal plate at 50 m depth. System noise floor of 5 nT/s indicated by dotted line.

Figure 4 shows on- and off-time decays extracted from a production survey data set. The four curves illustrate the response from low, moderate, high and very high conductance sources in the survey area. The low (black) and moderate (blue) conductance decays have similar amplitude and decay characteristics in both the on and off-time data. The on-time response from the high (green) conductance decay has a decay rate similar to the off-time response however the amplitude is approximately double. The decay rates and amplitudes of the very high conductance source are markedly different and demonstrate the additional sensitivity and discrimination available in the on-time data set.

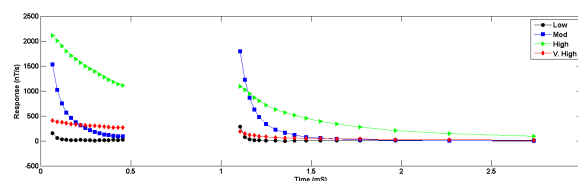


Figure 4: On and Off-time dB/dt decay data from four selected anomalies. The responses indicate low conductance (black circles), moderate conductance (blue squares), high conductance (green triangles) and very high conductance (red diamonds) geologic sources.

Aerotem Survey Examples

In the following, we describe four projects which illustrate the use of the AeroTEM system.

Copper and Molybdenum Porphyry Deposits – Western Cordillera, Canada

Aeroquest was contracted by the government of British Columbia (BC) to survey a large portion of interior BC and several known porphyry deposits. The AeroTEM electromagnetic data and magnetic data collected over the Bell Deposit are very useful in mapping the core of the deposit and the alteration halo which surrounds the deposit (See Figure 5). The magnetic data are responding to the Babine intrusions that are related to the alkalic porphyry systems.

Exploration for porphyry systems requires an airborne EM system that is capable of surveying in challenging terrain since many porphyry deposits are found in mountainous cordilleran environments. In addition, the EM system must be able to map subtle resistivity variations for the definition of the alteration zonation in and around the porphyry.

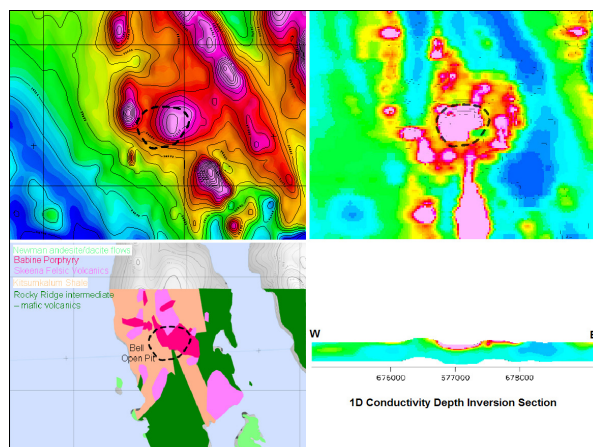


Figure 5: AeroTEM and magnetic results over the Bell Copper Porphyry Deposit. Top Left: Magnetics; Top Right: AeroTEM resistivity depth slice from 1D inversion; Bottom Left: Simplified Geology; Bottom Right: 1D resistivity inversion section.

Uranium in Paleochannels - Namibia

Paleochannel-hosted uranium mineralization was discovered in the Namib Park region of Namibia in the 1970's and 1980's. Airborne radiometric survey data effectively maps this mineralization in the very near surface, but does not provide information about mineralization at depth. The results from an AeroTEM helicopter-borne electromagnetic survey flown over a large portion of this area effectively map the paleochannels which host the uranium. The survey data are analysed to provide a 3-D model of the paleochannels to depths of up to 200 m. These 3-D models have identified new paleochannel systems, and are being used to effectively guide drilling programs within known paleochannels systems. Integration of the airborne radiometric, AeroTEM, and drilling data sets facilitate an efficient and effective exploration program for paleochannel-hosted uranium mineralization in this area.

Figure 6 depicts the results of the 3-D model. Note that the paleochannels which occur in the south-western portion of the survey area come to surface, but a paleochannel in the north-eastern portion of the survey area is buried. This blind paleochannel was previously unknown and became a priority exploration target for uranium mineralization.

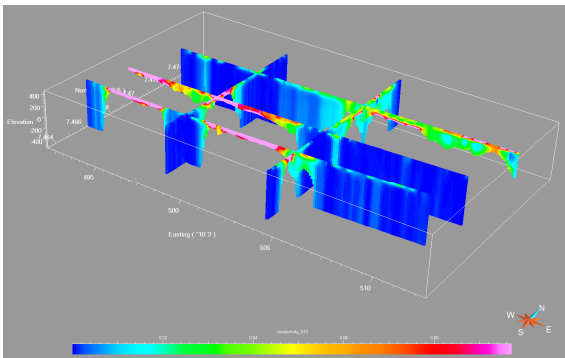


Figure 6: 3D model constructed from 1-D inversion results depicts paleochannels at surface and at depth (image courtesy of Mira Geosciences Advanced Geophysical Interpretation Centre).

On-shore Petroleum Exploration – Mozambique

A multi-parameter airborne geophysical survey was carried out in south-eastern Mozambique (Pfaffhuber et al, 2009). The purposes of the program were to characterize the response over, and in the vicinity of, known gas seepages in the area, and to apply this signature to identify the more important structures and horizons in the license area. The survey was also performed to provide complete and consistent coverage over the project area in order to improve the overall understanding of the near-surface geology toward a more efficient exploration programme.

The airborne survey covers a portion of the Mesozoic Urema Graben, a half-graben with the main fault located just west of the Inhanga High. Several transfer faults intersect the graben within the survey area. A well drilled in 1935 reportedly yielded gas, and gas is seeping to the

surface at several places along the main bounding fault on the east edge of the graben.

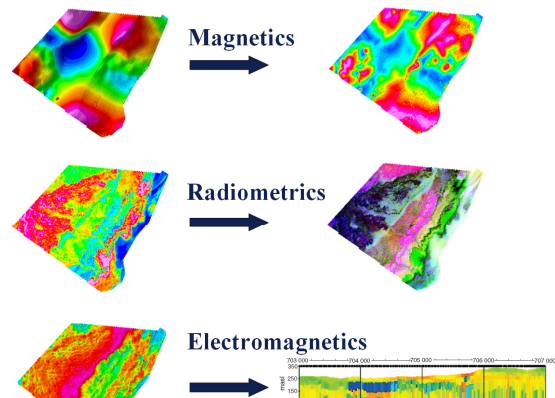


Figure 7: Survey results from the AeroTEM project in Mozambique clearly define the stratigraphy and facilitate structural interpretation.

The AeroTEM system was selected for its good depth penetration, high bandwidth and excellent spatial resolution. The survey lines were flown perpendicular to the graben in a NW–SE direction with 500 m line spacing. Magnetic and radiometric data were acquired using Aeroquest's ultra-high resolution (UHRAM) fixed-wing system using the same survey parameters.

The data have been usefully interpreted to map the location and distribution of the various lithologies across the survey area. This mapping effort is useful for the determination of potential structures, both parallel and perpendicular to the graben boundary and for guiding the ground truth process.

The AeroTEM data have been very useful for the interpretation of the structure in the upper 200 m where the seismic data do not provide great detail. The interpretation also facilitates the planning of further seismic surveys, including:

- avoidance of transfer faults or other structures that may degrade the seismic data
- avoidance of lithologies that may attenuate/scatter the seismic source energy
- Locate seismic lines to optimize for new understanding of the geology

Integration of Seismic and AeroTEM Data for aquifer mapping – Canada

Buried valleys occur in many regions throughout North America and Northern Europe and can often represent important sources of groundwater (Oldenborger et al, 2010). An understanding of these valleys is often hindered by a lack of surface expression and geometric

complexity. Airborne EM provide rapid, high-resolution coverage at a relatively low cost.

The Spiritwood Valley aquifer extends 500 km from Manitoba to South Dakota. The northern portion which lies in Canada was surveyed with the AeroTEM system. The EM results provide a clear picture of the structure within the valley and the complexity of the channel system beneath the covering layer. Figure 8 shows the preliminary interpretation of the new valley boundaries, the main valley axis, and a new major secondary valley which occurs parallel and northeast of the main axis. The data are currently being analysed and integrated with seismic and ground resistivity survey data to determine the relationships between the various channels.

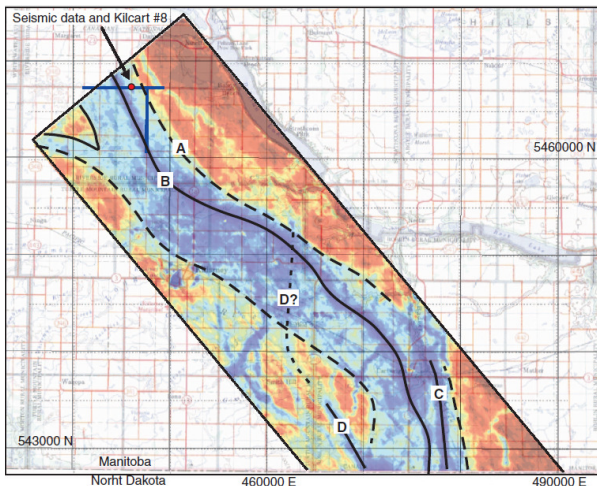


Figure 8: Interpreted features from the AeroTEM data; A: revised valley outline; B: incised valley axis; C: major secondary valley; D: dipping valley. (Oldenborger, 2010).

In Figure 9, we see the importance of integrating other geophysical data sets into the final interpretation. In the southern portion of the survey area, two channels are clearly mapped by the airborne EM data (labeled as 'b' and 'l' in the seismic section), and the seismic data clearly identify channel 'l' and 'c', and to a lesser extent, 'b'. Channel 'c' is not readily interpreted from the EM data, because the infilling sediments are of the same conductivity as the host. The integration of the two surveys allows for the identification of all three channels, and the AEM results facilitates the discrimination between sand and gravel infill and clay-rich infill.

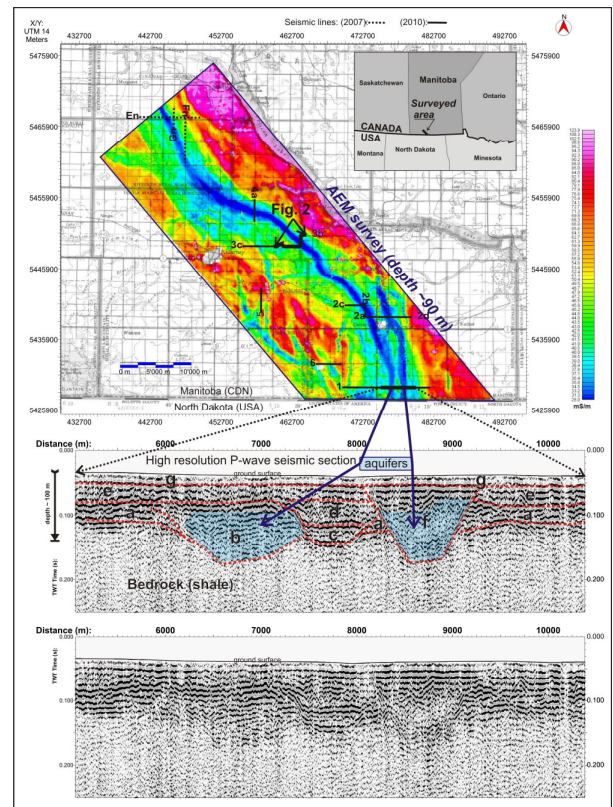


Figure 9: Airborne EM results across the survey area with P-wave seismic sections with and without interpretation of three paleochannels. (Pugin et al, 2011)

Conclusions

The AeroTEM system's rigid structure makes the recording of interpretable on-time data possible, and allows the system to perform in even rugged terrain. The broad applicability of this particular HTEM technology is seen in its effective application to a variety of exploration projects. For many applications, the full strength of airborne EM surveys are often seen when the resulting data sets are interpreted and integrated with other supporting geoscience information.

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