Preview

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Minerals geophysics

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Minerals geophysics

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Aspects of innovation II

In this issue of *Preview,* we have another in the series by geophysical contractors and consultants who are innovators in their field. Andrew Carpenter from Expert Geophysics describes aspects of the development of the MobileMT system, an advance in airborne magneto-tellurics (MT) surveying. As a proponent of MT for use in a wide range of resistivity environments, and a past user of the technique in ground surveys, continued development of an airborne version is definitely of interest. I invite you to read Andrew's contribution below.

And, as I wrote in the last issue of *Preview*, if you or your organisation have a story of innovation in mineral exploration geophysics you'd like to tell, please get in touch. We'd love to hear it.

Expert Geophysics driving ground-breaking new developments in airborne AFMAG technology

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MobileMT in the Patterson Ranges.

Australia is an ancient continent, and much of its undiscovered mineral wealth is masked by a thick cover of weathered rock, regolith, sediment, and soil, posing formidable exploration challenges. Mineral explorers lack the technological tools to discover new resources buried beneath the cover. Expert Geophysics, a Canadian company with offices in Toronto, Perth, and Johannesburg, is leading the development of the latest Airborne EM technologies capable of penetrating Australia's deep and highly conductive cover.

Historically, airborne electromagnetic induction methods (AEM) with controlled primary field sources have been given attention by many specialists. Frequency-domain systems (FDEM), which use a harmonic magnetic field source, were under constant development and active use during the last century. After many decades of service, the frequency-domain method remains limited in its depth of investigation despite being sensitive to a broader range of resistivities. Time-domain systems (TDEM) excited by a step pulse have replaced frequency-domain systems for most exploration applications due to a greater depth of investigation. Many improvements to airborne time-domain systems were achieved during the last 20 years. However, several limitations persist that restrict the use of the time-domain AEM principle, including:

- The depth of investigation only sometimes meets exploration requirements, especially in conductive environments and areas with conductive overburden.
- The measured signal and depth of investigation are highly dependent on the transmitter height, tilt, and geometry.
- This dependence creates difficulties and restrictions for surveys in rugged terrain.

- There are challenges in getting a measurable response in relatively resistive terrain (commonly higher than 1000 ohm-m) and subtle resistivity contrasts.
- There are parasitic IP and SPM effects on measured induction under specific near-surface conditions.

Methods that exploit natural electromagnetic fields (magneto telluric and magneto variational, AFMAG) can overcome the limitations of airborne systems with controlled primary field sources. A comparative estimation of the depth of investigation of different airborne electromagnetic principles is presented in Figure 1.

The first period of theoretical development and practical usage of AFMAG (audio-frequency magnetic technique) as an inductive electromagnetic method exploited audio-frequency natural magnetic fields. One of the main reasons for the development was the potential to provide significant depth information without exploiting technically limited primary field, controlled sources. McPhar Geophysics Limited commercially used the airborne AFMAG system in the 1960s and early 1970s. The company then shifted their commercial focus to radiometry, and thus the development of electromagnetic methods was terminated.

The Dicon/Q-Trac airborne EM system introduced in 1997 by Barringer Geosystems Inc (USA) based on natural source AMT/MT was listed under the testing/R&D status. The Dicon system, in its test configuration, measured orthogonal components of the E and H fields.

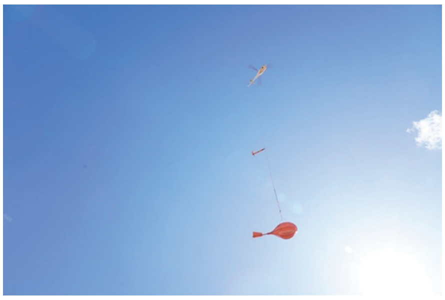
High-Sense Geophysics (Canada) further developed an AFMAG system in 1998 with Petr Kuzmin. The first field test, in 1999, was successful and promising. The development was terminated after consolidation with Fugro.

Other airborne AFMAG prototypes in 2001 and 2002 developed by Geotech Ltd. played the role of transitional and non-commercial designs. The AirMt system with three orthogonal inductive receiver coils was announced as being at an R&D stage and was not commercially available. The AirMt system measured the rotational invariant part of the in-phase and quadrature transfer functions in the frequency domain for three magnetic geometrical components from the airborne receiver and three magnetic geometrical components at a stationary reference base station.

The tipper-type, magnetovariational airborne platform ZTEM became the next generation of AFMAG technology and the first commercial airborne 'AFMAG' system more than 40 years after the original AFMAG. The ZTEM system is based on measuring the induced signal's vertical magnetic component, primarily caused by lateral resistivity variations in the subsurface geology. ZTEM outputs are the tipper components as the transfer function of a vertical magnetic field; Tipper measurements (Hz/Hx or Hz/Hy) are dimensionless, cannot resolve layered geology, and tipper responses are considerably diminished for compact 3D bodies compared to 2D geological strikes. Since the tilt of the flying coil is unstable during a survey, ZTEM uses attitude sensors to correct the source of the error. Still, the error correction quality is affected by unknown differences in the horizontal components between the audio-magnetic field magnitudes at the reference and in-flight positions.

All the systems from the AFMAG family suffer from bias effects of the recorded data, arising from weak natural signals. These distortions cannot be corrected by signal filtering, and, as a result, significant systematic errors and false anomalies occur. This technical problem has been solved with the development of the MobileMT technology.

The MobileMT system, introduced in 2018, was developed by Expert Geophysics Limited to continue the evolution of the airborne electromagnetic natural fields technology 12 years after the introduction of ZTEM and 60 years after the first commercial AFMAG system.



MobileMT in Western Australia.

MobileMT employs an airborne receiver which comprises three orthogonal induction coils to take measurements of alternating magnetic fields, and a ground electric base station, which measures reference and signal electric fields in two perpendicular directions with four pairs of electrodes. The E-field base station includes the 'reference' orthogonal pair of grounded lines, utilised to eliminate local noise, and correct for data bias distortions. In the MobileMT technology, the E-field data is used to reference the primary natural electromagnetic field variations to facilitate the separation of the time-variance from the space-variance of the measured fields.

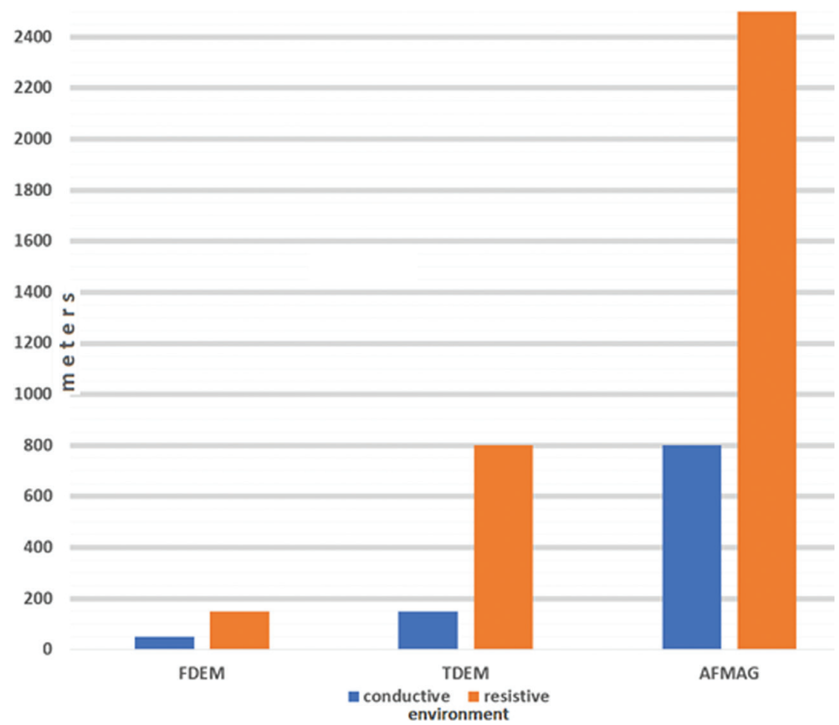


Figure 1. *Approximate depth of investigation estimation of different airborne electromagnetic principles.*

The signal-to-noise ratio for the electrical field measurements is considered much higher than the signal-to-noise ratio for the magnetic field, which is one of the advantages of the MobileMT system. The electric component of MobileMT is one of the features that distinguish it from its predecessors.

The technical solutions realised in the airborne MobileMT technology provided exploration capabilities that overcome the limitations of other AEM systems based on different principles, including those using controlled primary field sources.

The specific technical advancements that enable exploration advantages include:

- Measurement of magnetic field variations with three orthogonal coils (total field). This provides sensitivity to any direction of geoelectrical boundary, from horizontal to vertical.
- Measurements are obtained over three decades of frequency, from 19 Hz to 26 kHz. This allows imaging of near-surface structures and those at > 1 km depth, depending on the conductance of the geologic environment.
- The frequency range is divided into 30 windows that provide high in-depth resolution and a good opportunity for data selection, depending on cultural noise sources, natural EM field signal, and exploration goals.
- The high sampling rate of the airborne data and the base station data result in bias-free and denoised data.

The main advantages of the natural field method, in general, include:

- The depth of investigation consistently exceeds the capabilities of systems with controlled sources.
- The method is sensitive to conductors and resistivity differences in the range of thousands and tens of thousands of ohm-m, which is challenging for existing time-domain systems. At the other end, for time-domain systems, the response from superconductors (hundreds and thousands of Siemens) is not visible in the off-time channels of the dB/dt stream. For the natural field EM principle, it is not a limitation.
- There is no critical dependence on the terrain clearance of the system. This allows for less aggressive flying in rugged terrain conditions, improving the overall safety of data acquisition.

IP and SPM parasitic effects are inherent to impulse time-domain systems that badly influence the inductive response. These effects are not formed and do not distort the secondary electromagnetic field data for methods using natural fields.

An excellent example of the advantages of MobileMT technology was acquired at Coda Minerals Elizabeth Creek project, located in the Olympic Dam district, which is a belt of Cu-enriched basement of the Gawler Craton, South Australia. The district's Mesoproterozoic and older crystalline basement is overlain by a thick succession of Neoproterozoic, Cambrian, and younger sedimentary basin rocks known as the Stuart Shelf. The copper-cobalt deposits (fine-grained sulphides) are hosted by flat-lying, undeformed Late Proterozoic sedimentary rocks deposited on the Stuart Shelf. These platform sediments are known as the 'Cover Sequence,' they unconformably overlie the complexly deformed and metamorphosed igneous rocks of the Archaean basement. The Emmie Bluff prospect in the north of the Elizabeth Creek project is an underground target with a top of mineralisation at around 400 m depth from the surface.

Historically, several active source airborne EM surveys have been flown in South Australia, including VLF (very low frequency) and frequency domain and time domain surveys. Due to the presence of highly conductive cover, the success of these methods to aid in the location of ore deposits has been limited. The Gawler Province is an area approximately the size of France, with very little fresh rock outcrop. As such, understanding the subsurface relies on information from drill holes and non-invasive geophysical methods. Despite the conductive cover/regolith, which limited the success of other airborne EM technologies, the MobileMT data successfully mapped the strata-bound zones with related mineralisation at depth.

Figure 2 shows the resistivity section derived from 1D inversions with the

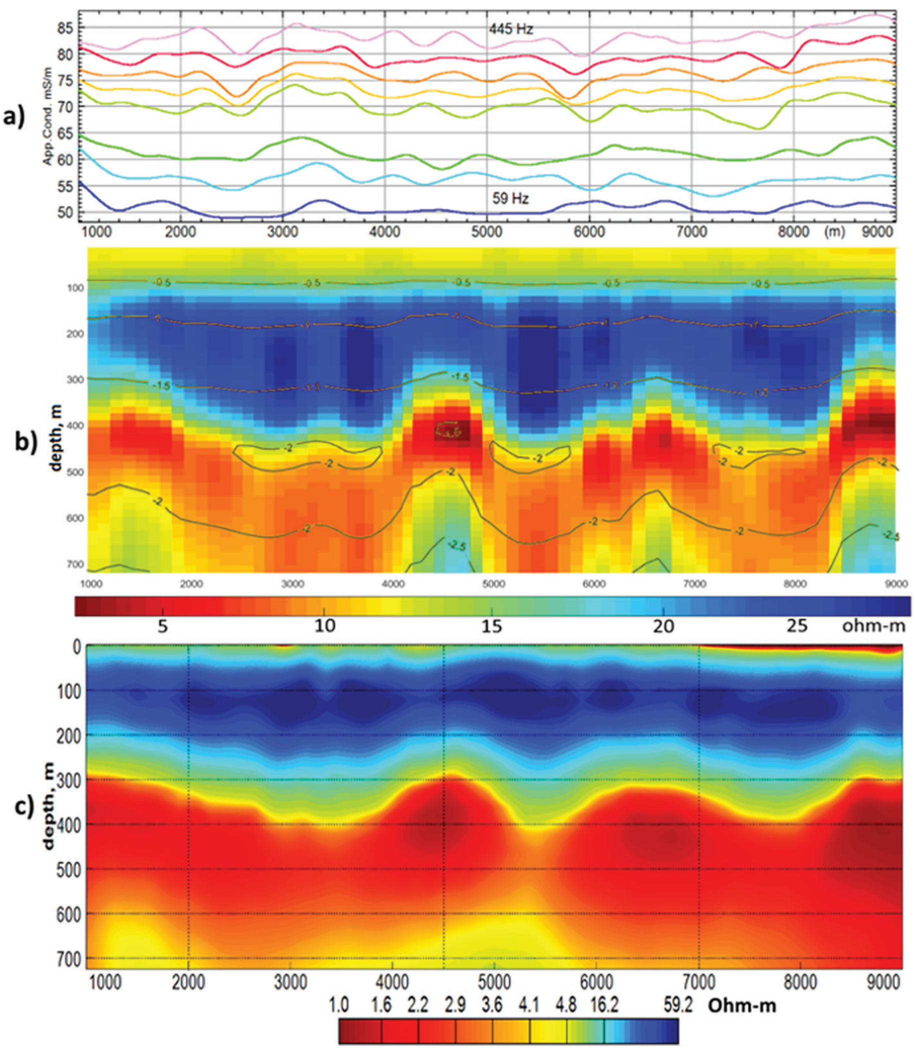


Figure 2. *MobileMT apparent conductivity profiles (a); resistivity section from the 1D model with contours of the data inversion logarithm of sensitivity (b); resistivity section from the 2D model (c) along a survey line from the Emmie Bluff prospect over a known mineralisation.*

logarithm of the inversion sensitivity contour lines for the DOI reference. Corresponding resistivity-sounding curves from the measurement stations along the line are also shown. The resistivity section resulting from 2D inversions of the data along the same line is shown in the final figure. The 1D and 2D inversion results are consistent; just absolute values of resistivity derived from the 2D model should be closer to reality for non-layered conductors.

Ground magnetotelluric data was acquired between 0.001 and 250 Hz with a site spacing of approximately 500 m. Twelve frequencies were involved in the MobileMT data inversion between 27 and 445 Hz. The depth range of the sections is limited by the MobileMT depth of investigation estimated for the survey area. The results of inverting the ground magnetotelluric data vs the MobileMT data are provided in Figure 3. This field example demonstrates exploration capabilities of the airborne MobileMT technology in a highly conductive environment with decent depth of investigation. Direct comparison of the airborne EM with ground MT resistivity shows a good match between the two resistivity-depth images.

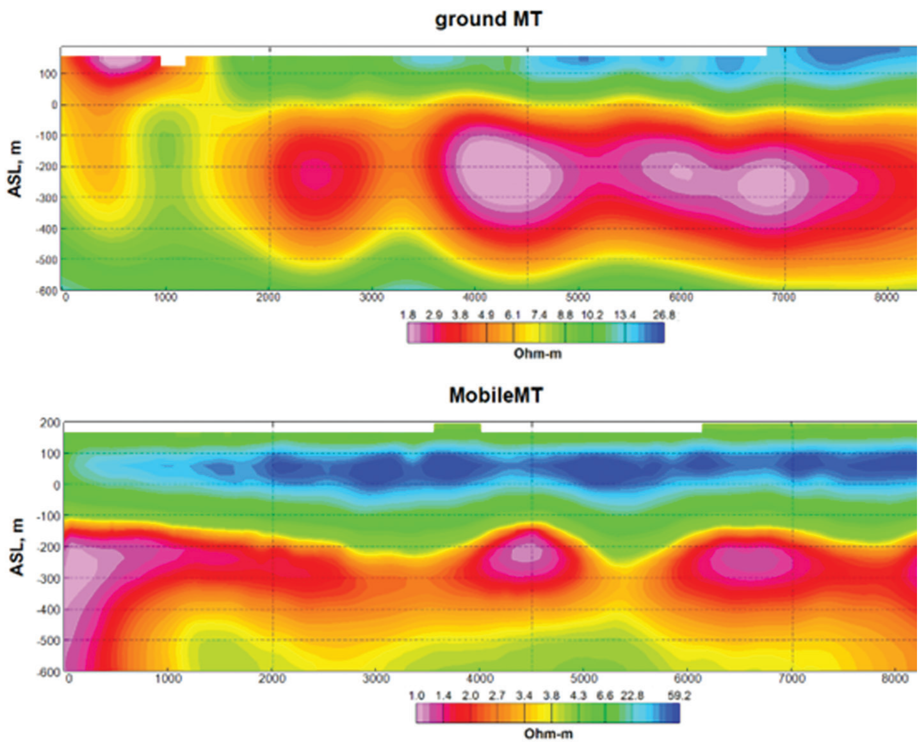
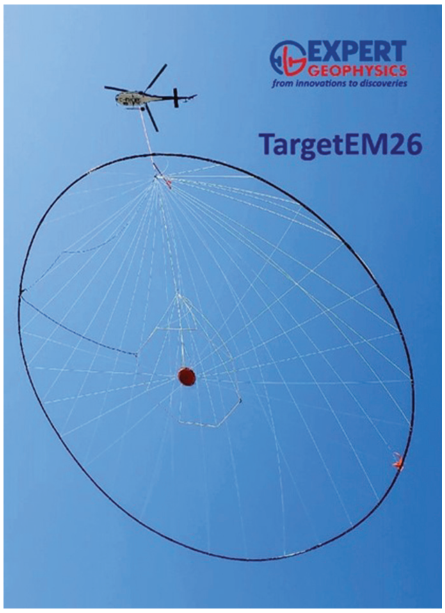


Figure 3. *Resistivity sections over the same line derived and inverted from MobileMT and from ground MT data provided by CODA Minerals. Emmie Bluff block.*

Expert Geophysics is a company primarily driven by R&D; there are more technicians and engineers on staff than there are geoscientists. The engineering team led by Petr Kuzmin continues to pioneer the latest in AFMAG technologies, with improvements to the MobileMT technology rolling out regularly. Andrei Bagrianski, the company's President and Alexander Prikhodko, the company's Chief Geophysicist, work closely with clients to find new technological solutions to today's geophysical exploration problems. An exciting new development driven by the industry's need for new technology includes the TargetEM system, a new patent pending airborne time-domain electromagnetics system, which combines the latest achievements in electronics and sophisticated signal processing techniques to extend the capabilities of current airborne time-domain systems into the future. The system is designed to provide VLF, AFMAG, and time-domain EM data, all acquired simultaneously on a single platform. The technological leap forward offered by the TargetEM is only just being realised, with several software and processing vendors currently working towards taking advantage of the capabilities of this new exploration tool.



TargetEM 26 now flying in Australia.

As technological advancements continue and improvements are made to the hardware and software involved in the MobileMT technology, it is anticipated to become an increasingly reliable and versatile tool for the mining and resource industry. Advancements to the 1D modelling used to invert the apparent conductivity data and retrieve the resistivity depth distribution are ongoing to improve the agreement between the theory and the real-world implementation. In addition, 2D inversion codes, such as MARE2DEM, and 3D inversions, compatible with MobileMT data, can provide more accurate resistivity models in specific circumstances. With the advent of the TargetEM, which sees the merging of the very best of time domain, VLF and AFMAG technology, the future looks bright for Airborne EM surveying globally and in Australia specifically as the ability to acquire data across a broader range of resistivities and explore deeper from the air than ever before offers new and much needed technical capability to Australian mineral explorers.