Airborne MobileMT: Exploration Advancements through Technical Solutions

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BIOGRAPHY

Alexander Prikhodko, Ph.D., EMBA, P.Geo, is an exploration geophysicist with diverse experience in airborne and ground geophysics worldwide. For the past two decades, he has focused on airborne electromagnetic methods, their exploration applications and data interpretation.
Andrei Bagrianski, Ph.D., P.Geo., has over 35 years of professional experience in the acquisition, processing, and interpretation of airborne and ground geophysical data for a wide range of applications.
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SUMMARY

Airborne electromagnetic (EM) systems for mineral exploration vary in design and performance, with each method having unique strengths and limitations. MobileMT, one of the latest developments in airborne EM, utilizes natural electromagnetic fields over a broad frequency range, combining magnetotelluric (MT) and magnetovariational (MV) principles. This approach addresses the limitations of traditional EM methods, such as limited depth penetration, resistivity range detectability, and frequency range ambiguities. MobileMT technology includes three orthogonal inductive coils and grounded electric lines, enabling precise, rotationally invariant data acquisition and comprehensive admittance tensor calculations for accurate subsurface resistivity mapping.

Field examples from the Athabasca Basin and Saddle North porphyry Cu-Au deposit demonstrate MobileMT effectiveness. In the Athabasca Basin, the system provided high-resolution geological structures, including the horizontal unconformity contact, by integrating high and low frequency data. At Saddle North, it successfully mapped resistivity variations related to mineralized zones, showcasing its depth range and sensitivity to a mineralization-controlling structure.

MobileMT's innovative design and strong performance in various geoelectrical, geological and terrain conditions make it a powerful tool for mineral exploration. It overcomes traditional EM system limitations in many aspects, delivering comprehensive results.

Key words: airborne electromagnetics, MobileMT, mineral exploration.

INTRODUCTION

Airborne electromagnetic (EM) systems used in mineral exploration are built on various principles, each with unique technical designs that result in different performance levels across geoelectrical conditions. The limitations in the subsurface exploration of airborne EM methods and their technical implementations in different systems can be both fundamental and superficial affecting the capabilities of geological exploration. For instance, limited depth penetration of systems with controlled primary fields is overcome by the use of 'passive' field systems. However, ambiguities in recovering the total depth range, beginning from the near surface, in the passive field domain are determined by the frequency set width. The limited resistivity detectability range of the 'impulse' or off-time-domain method is significantly expanded in frequency-domain measurements. Sensitivity to contrasts or absolute resistivity differences and the diversity in recovering complex geology and structures are defined by the geometrical components of the receivers.

The airborne technology MobileMT, one of the latest developments in airborne EM, exploits natural electromagnetic fields in the broadband frequency range, combining measurements with moving three orthogonal inductive coils and stationary two pairs of orthogonal horizontal grounded wires. The technology exploration capabilities are defined by the method's fundamental advantages such as the existence of the primary field underground, frequency-domain data nature, and by founded specific technical solutions which overcome limitations of other airborne EM systems in challenging geoelectric and terrain conditions.

The technology exploration advantages are examined in relation to implemented technical solutions with the support of field examples.

METHOD AND SYSTEM CONFIGURATIONS

The operating principle of the airborne natural-field MobileMT EM technology is a combination of magnetotelluric (MT) and magnetovariational (MV) concepts (Prikhodko et al., 2022). Currently, there are four modifications to the MobileMT system, tailored to specific survey requirements or terrain conditions – the main basic model MobileMT; the light version MobileMTm with precise positioning and magnetic field horizontal gradiometer; the drone version, MobileMTd, with expanded lowest frequencies range; the passive field component integrated into time-domain system TargetEM.

The measuring system for all configurations includes two main parts:

- Three orthogonal dB/dT inductive coils in a teardrop-shaped shell towed below the helicopter. Variations of the measured magnetic field (H-field) are recorded digitally in an acquisition system placed inside a helicopter. It is unnecessary to monitor or control the tilt precisely because the measurement system provides rotationally invariant total-field data.
- Two pairs of independent grounded orthogonal (X and Y) electric lines positioned a few meters apart for measuring ‘main’ and ‘reference’ variations of the electric field (***E***-field). The data from the stationary electric field variations measurement system are recorded similarly to the mobile H-field by a separate acquisition system.

The denoised and corrected ***E***-field data represent the primary natural electromagnetic field variations. They facilitate the separation of the time-variance from the space-variance of the measured fields (like in MV). The combination of magnetic (***H***) and electric (***E***) fields variations are used for admittance tensor calculation introduced by Thomas Cantwell in 1960 as $\boldsymbol{Y} = \boldsymbol{H}/\boldsymbol{E}$ and, ultimately, for the calculation of apparent conductivities corresponding to different frequency bands:

$$\sigma(\omega)=\mu\omega|\boldsymbol{Y}^2|,$$

where μ is the magnetic permeability of free space, and ω is the angular frequency.

Having magnetic and electric field data variations measured in different relative orientations, magnitudes of total H and E vectors independent of the sensors’ spatial attitudes are calculated at the same frequency and time [Prikhodko et al., 2024].

Table 1 describes the main capabilities and advantages of the MobileMT technology and their relation to technical solutions.

Table 1. Technical solutions and their outcomes in the system’s capabilities

Technical feature	Outcome result
Primary field – naturally occurred subsurface electromagnetic plane wave	Depth of investigation consistently exceeds the capabilities of controlled source airborne EM systems. There is no critical dependence on the system's terrain clearance.
Three orthogonal receiver coils (Total Field)	capability to detect geoelectric boundaries in any direction
Remote reference station	de-noised and bias-free data
Electric and Magnetic components	sensitive to the absolute conductivities
Frequency domain data	Sensitivity to differentiations in a full range of rocks and minerals resistivity. The method is sensitive not only to conductors but also to resistivity differences in the range of thousands and tens of thousands of ohm-m
Broadband frequency range, in 3+ decades	imaging of near-surface structures as well as those at > 1 km depth, depending on the conductance of the geologic environment
The frequency range is divided into 30 windows	high in-depth resolution and a good opportunity for data selection, depending on cultural noise sources, natural EM field signal, and exploration goals

FIELD EXAMPLES

The field examples below demonstrate the airborne EM technology capabilities in relation to the implemented technical solutions included in Table 1.

Example 1

The example is from a survey of an area in the Athabasca Basin. The presented survey line is located between the McArthur River Mine and the Millennium deposit in the southeastern part of the Basin. Drill holes in the area confirm the position of the unconformity contact at 600-650 m depth from the surface (Basin Uranium Corp., 2023).

The resistivity sections along the same survey line in Figure 1 demonstrate the importance of high frequencies along the low-middle range of frequencies for recovering geology with high in-depth resolution. Including high frequencies in the inversion process in the resistive environment of the Athabasca Basin provides a clear definition of the horizontal unconformity contact and outlines discrete conductors near the contact with high resolution. The total field data, derived from three orthogonal receiver coils, are sensitive to any direction of geoelectrical boundaries – from horizontal to vertical, outlining geology of any complexity. The EM data inversions in Figure 1 are done without constraints with the initial model as a uniform half-space.

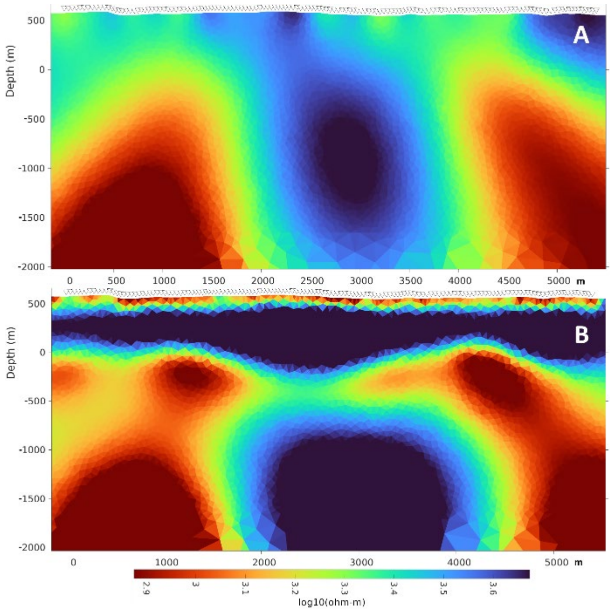

Figure 1. Resistivity-depth sections along a survey line in the eastern part of the Athabasca Basin. A – inverted with 12 frequencies between 26-338 Hz B – inverted including three additional high frequencies 5382, 6786, 8550 Hz.

Example 2

Saddle North porphyry Cu-Au deposit is located in the Iskut district of northwestern British Columbia. Intrusive rocks of Saddle North intrusive complex (units TrJmd and TrJmdu in Figure 2) are closely associated, spatially and genetically, with porphyry copper-gold mineralization by the close spatial association of porphyry-style stockwork veining, alteration assemblages, and elevated grades of copper and gold (Greig et al., 2020). The more conductive zones in resistivity distribution (Figure 3) most likely correspond not just to the intrusive rocks, which are continued to depth, but to the alteration zones following the deposit. The deposit geological model (GT Gold, 2020) depicts a well-developed, steeply plunging potassic core that is associated with the highest-grade mineralization, and which lies within the bounds of intense QSP alteration, which shoulders the potassic alteration core (Figure 2, bottom). The high-grade mineralization core zone with grades exceeding 1.0% CuEq and 1.5 g/t AuEq reached from near surface to greater than 1,300 metres down-dip (GTGold, 2019). The comparatively conductive zone begins from the near-surface as well.

The case demonstrates the MobileMT system's capabilities of resistivity mapping in a wide range of depths beginning from the surface.

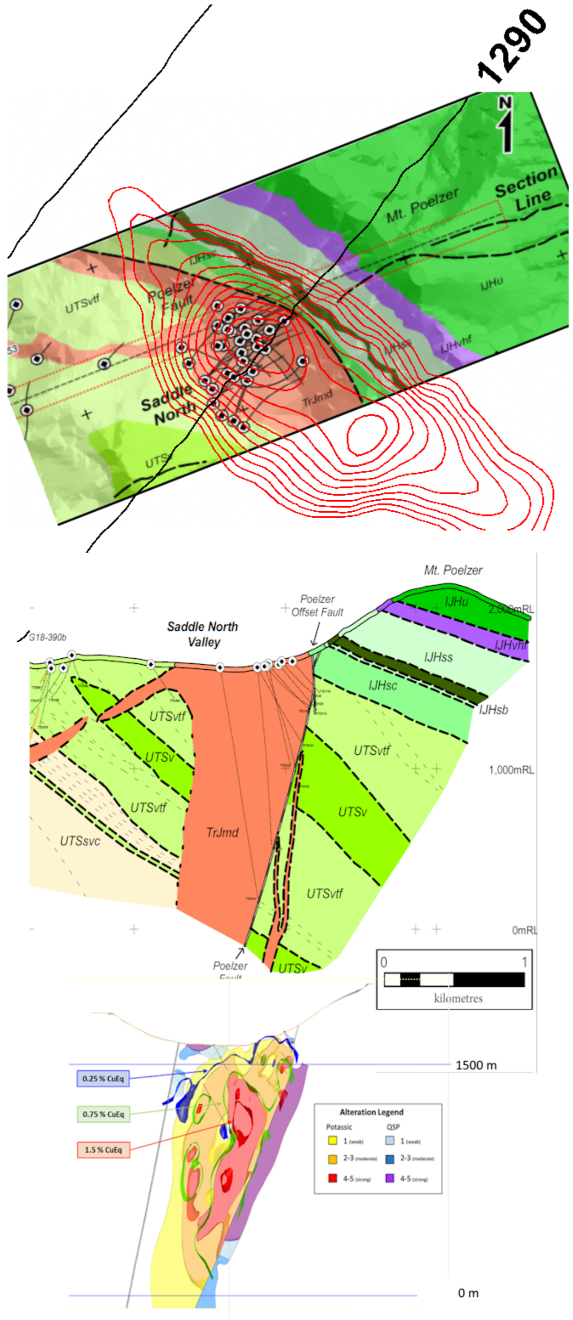

Figure 2. Geological map with contours of conductive anomaly 84 hz (top), geological section (middle), alterations section (bottom) over Saddle North porphyry deposit (Greig et al., 2020; GT Gold, 2020)

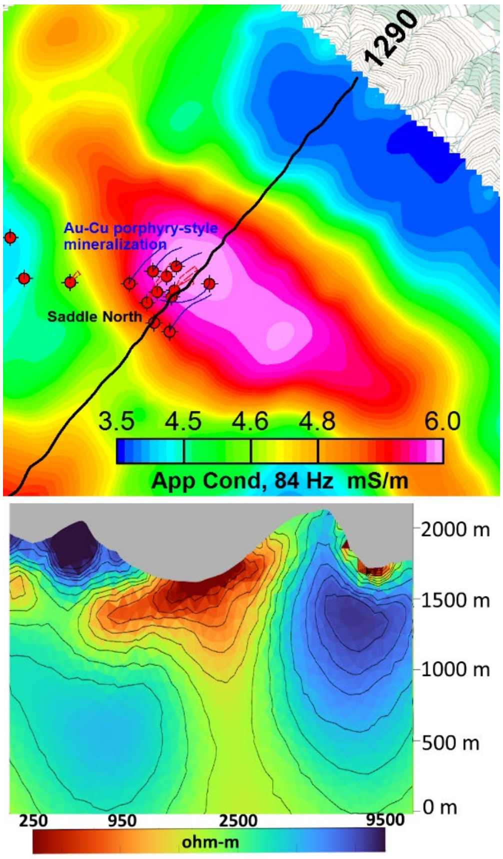

Figure 3. MobileMT apparent conductivity map (top) and resistivity section (bottom) over Saddle North porphyry deposit

CONCLUSIONS

Advancements in airborne EM passive systems for mineral exploration have significantly enhanced subsurface imaging capabilities, in the depth of investigation with covering near surface and deep structures, and in resistivity range detectability. MobileMT, a recent innovation in this domain, leverages natural electromagnetic fields across a broad frequency range to address the limitations of EM methods with controlled sources and previous developments in passive fields. By combining magnetotelluric (MT) and magnetovariational (MV) principles with innovative technical solutions, MobileMT offers robust performance across diverse geoelectrical and geological conditions.

MobileMT's design includes three orthogonal inductive coils and grounded electric lines, which enable precise, rotationally invariant total-field data acquisition. This facilitates accurate subsurface mapping by integrating magnetic (H) and electric (E) field variations for comprehensive admittance tensor calculations.

Field examples from the Athabasca Basin and the Saddle North porphyry Cu-Au deposit underscore MobileMT's effectiveness. In the Athabasca Basin, the system's high-frequency and low-frequency data provided clear resolution of geological structures, including the horizontal unconformity contact. At Saddle North, the system successfully mapped resistivity variations corresponding to alteration mineralized zones, demonstrating its depth range and sensitivity to comparatively near-surface and deep structures.

Overall, MobileMT's integration of the natural-field EM principle and versatile configuration make it a powerful tool for mineral exploration. MobileMT overcomes the limitations of other airborne EM methods and demonstrates field success, making it a valuable asset for airborne geophysical surveys in diverse geological settings. As the technology evolves, it is expected to further enhance the accuracy and efficiency of subsurface exploration.

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