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Application of MobileMT in Mineral Exploration: Examples from Porphyry, Epithermal, Orogenic Gold, and IOCG

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Abstract Summary

Resistivity methods are a fundamental in applied geophysics for mineral exploration. Airborne electromagnetic (EM) surveys enable efficient mapping of subsurface resistivity structures across large, often remote or inaccessible areas within a practical timeframe. However, the capabilities and limitations of airborne EM systems vary depending on their methodologies, which directly influence their depth of investigation and applicability. MobileMT, an airborne EM system that utilizes naturally occurring electromagnetic fields, offers a depth of investigation of up to 2.5 km—significantly deeper than any active-source airborne EM system under any geoelectrical conditions. MobileMT is sensitive to resistivity contrasts across a broad range and is capable of detecting geoelectrical boundaries regardless of their orientation. These detection capabilities make MobileMT particularly effective for exploring mineral systems with complex morphological and petrophysical characteristics. Resistivity reflects lithological variations, structural features, and mineralization-related alterations. It is effective for mapping and detecting both conductive ore bodies, such as sulfide-rich zones, and subtle resistivity contrasts associated with magmatic-hydrothermal systems and their structural controls. Depth models derived from MobileMT data effectively capture and characterize the resistivity signatures of diverse mineral systems across multiple geological settings worldwide. The case studies encompass the major types of gold-bearing systems, including porphyry, epithermal, orogenic, and iron oxide copper gold (IOCG) deposits. Given the diversity in host rock compositions, alteration intensities, structural architectures, overprinting fluid events, post-mineralization tectonics, and varying levels of erosion, no single geophysical model universally applies to all mineral systems. Despite this complexity, field investigations demonstrate that MobileMT can reliably detect a wide range of mineral systems, including those buried at depth or obscured beneath highly conductive post-mineral covers. Examples from various geological contexts illustrate the effectiveness of resistivity imaging with MobileMT for both known deposits and areas with high mineralization potential.

Introduction

Airborne electromagnetic methods based on controlled-source induction have long been used in mineral exploration. Early frequency-domain systems, while effective across a broad resistivity range, are limited in depth investigation. Frequency-domain and time-domain electromagnetic (TDEM) systems were the first to be used and tested. Over the past two decades, significant advancements in TDEM technologies have improved resolution and operational efficiency. However, fundamental limitations remain, particularly in penetrating highly conductive cover, managing signal decay at depth, and maintaining sufficient signal-to-noise ratios. Passive-source electromagnetic methods, which utilize natural electromagnetic fields, such as magnetotellurics (MT) offer solutions to many kind of challenges. These methods enable deeper penetration without the constraints of airborne transmitters. This paper introduces MobileMT, an advanced airborne EM system that leverages natural fields to achieve resistivity imaging down to depths of 2.5 km. We present the key technical innovations that enable this capability, along with field examples from diverse geological settings. These case studies demonstrate the system's applicability across various mineral exploration targets and geoelectrical conditions, highlighting MobileMT as a significant advancement in the evolution of airborne geophysical methods.

MobileMT Technology

The MobileMT system, introduced in 2018 by Expert Geophysics Limited, represents a advancement in airborne natural-field electromagnetic (EM) technology. It follows the development of ZTEM, launched 12 years earlier, and builds upon over six decades of progress since the first commercial AFMAG systems. Jansen and Cristall (2017) anticipated such advancements, suggesting that future systems would employ three-component receivers to capture vector data or total-field measurements.

MobileMT utilizes an airborne sensor composed of three orthogonal induction coils to measure time-varying magnetic fields, combined with a ground-based electric field reference station. The base station consists of four electrode pairs configured in two perpendicular directions to capture the horizontal components of the electric field. One orthogonal pair serves as a reference to suppress local noise and correct potential data bias, following principles outlined by Labson et al. (1985). This configuration enables the separation of temporal and spatial variations in the measured fields. A key advantage of MobileMT is the higher signal-to-noise ratio in the electric field measurements compared to magnetic components, enhancing overall data quality.

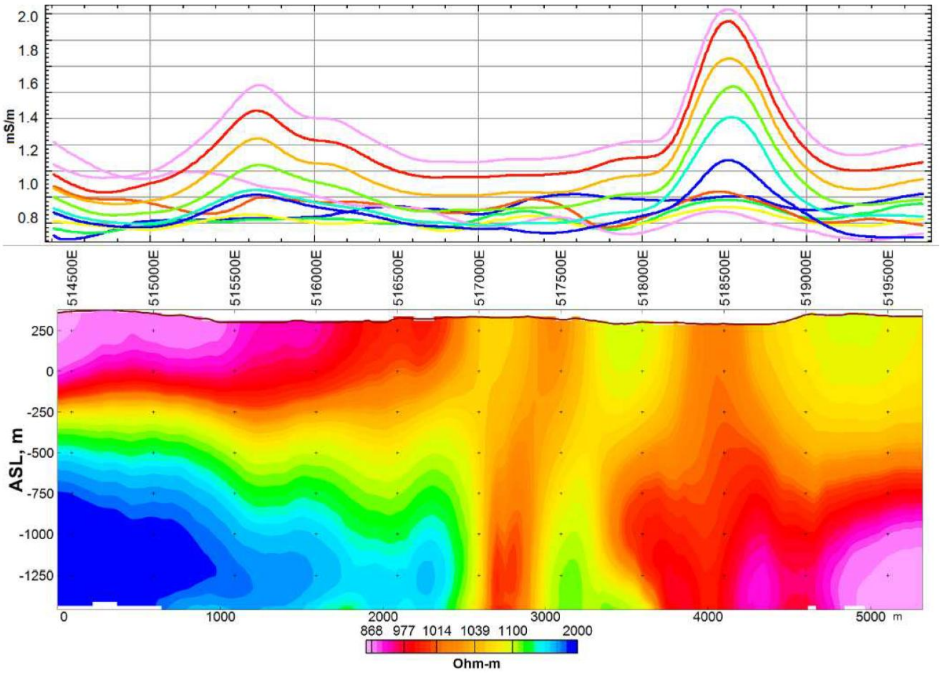
The system operates within a frequency range of 17 Hz to 21,000 Hz (depending on a platform, heli- or drone- borne), divided into 30 discrete frequency bands. However, the final set of usable frequencies depends on the prevailing strength of the natural EM fields during data acquisition. MobileMT records three orthogonal magnetic field components, allowing calculation of the total magnetic field without requiring attitude corrections, thereby eliminating related errors. The ground basestation records two horizontal components of electric field variations. The synchronized time series datasets (Ex, Ey, Hx, Hy, Hz) forms the basis for calculating admittance parameters across selected frequency bands.. A Fast Fourier Transform (FFT) converts the time-domain signals into the frequency domain. Subsequently, admittance matrices are computed to quantify relationships between the electric and magnetic components across multiple frequencies. The output is expressed in apparent conductivities (mS/m) for each frequency, supporting high-resolution resistivity imaging of subsurface geology.

Results

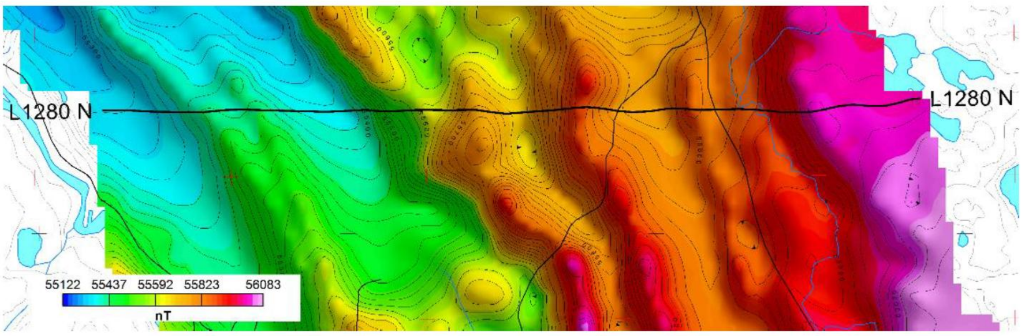
The MobileMT airborne electromagnetic (AEM) system offers significant exploration advantages compared to conventional controlled-source AEM methods. Its key innovations include three-axis magnetic field variations measurements, providing sensitivity to geoelectrical boundaries in any orientation, and a broad frequency range (17 Hz to 21 kHz) that enables imaging from near-surface to depths exceeding 1 km. The system's high-resolution division of frequencies into 30 windows allows flexible data selection and enhanced depth resolution. Additionally, high sampling rate (~74 kHz) for airborne and base station data ensure noise-free, unbiased results. MobileMT surpasses controlled-source systems in depth of investigation and can detect both highly conductive and resistive structures, overcoming typical limitations of the time-domain EM method (TDEM). It is also less affected by terrain clearance constraints, improving safety in rugged areas, and avoids distortions from induced polarization (IP) and self-potential (SPM) effects common in TDEM.

Several field case studies confirm the system's effectiveness across varied geological settings. At the Kainantu property in the New Guinea Thrust Belt, despite rugged terrain challenging traditional AEM, MobileMT successfully mapped conductive structures linked to epithermal Au-telluride and intrusion-related Au-Cu-Ag veins, as well as deeper dome-like features suggestive of porphyry Cu-Au mineralization potential. In Kazakhstan's Kendyktas Ridge, copper and copper-gold deposits are associated with stockwork and vein mineralization linked to metasomatized granitoids and quartz-chalcopyrite veins. These deposits—such as Chatyrkul, Jaisan, Ungurli, and Aktasty—are spatially related to Devonian subalkaline intrusives beneath Ordovician granites. MobileMT surveys identified deep resistive domes and vertical resistive “vents” coinciding with known ore zones, aligning with conceptual models of magmatic-hydrothermal systems, demonstrating the technology’s capability to detect ore-controlling structures at multiple depths.

The Tien Shan Belt hosts major gold deposits including Kumtor, an orogenic intrusion-related system formed around 5 km depth in hydrothermally altered Vendian sediments. A 2019 MobileMT survey over the Kumtor Trend detected low-resistivity zones correlating with gold-bearing altered metasediments and revealed deep dome-shaped conductive bodies interpreted as reduced intrusives or alteration zones. At the Aylmer Property in Northern Ontario (Figure 1), a resistive environment limited time-domain EM surveys. However, MobileMT successfully identified deep, weakly conductive structures and resistivity contrasts linked to mineralization controls, highlighting its superior sensitivity to subtle conductive features and complex geoelectric boundaries in resistive terrains.



(a)



(b)

Figure 1: a) MobileMT apparent conductivity profiles ranging from 42 Hz to 13,619 Hz and resistivity depth section (Aylmer Property in Northern Ontario, Canada); b) Magnetic field map with the survey line position.

Conclusions

Advancements in natural field airborne electromagnetic (EM) methods have greatly improved the effectiveness of mineral exploration. The passive-field EM system described operates by measuring variations in both magnetic and electric fields over a broad frequency range spanning three decades, utilizing up to 30 narrowly focused frequency bands. Magnetic field variations are captured by a mobile receiver positioned along three orthogonal directions, while a stationary base receiver records electric field data, supplemented by remote reference measurements to enhance signal quality and minimize noise. The system's ability to investigate depths ranging from shallow subsurface to beyond 1 km. They also demonstrate the system's precision in mapping geoelectrical boundaries with diverse geometries and detecting significant resistivity contrasts across a wide range of values. The technology has proven successful in identifying viable exploration targets. Its high spatial resolution allows for accurate detection of comparatively narrow, steeply dipping conductors and the detailed mapping of shear zones, among other complex geological structures. Although rock and mineral resistivity can vary considerably, the broadband airborne EM system remains a powerful exploration tool as long as petrophysical contrasts are within the depth and frequency limits of the system.

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