Exploration for deep gold bearing structures with natural field airborne electromagnetics

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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. His focus during the past two decades has been on airborne electromagnetic methods and its interpretation.

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SUMMARY

Airborne electromagnetic (AEM) methods have proliferated as a tool to aid in mineral exploration since their inception. To date the focus has primarily been on airborne systems that make use of controlled source primary field transmitters, however, the utility of such systems is limited in certain geoelectrical and topographic conditions. Passive AEM methods, which exploit the principles of natural varying electromagnetic fields, remove the necessity of having a controlled source primary field transmitter and overcome its limitations, depth of penetration, first. The source of primary signal for methods exploiting natural fields is currents induced in the subsurface primarily by thunderstorms and other activity in the ionosphere. The MobileMT system is one of the latest developments in the passive field AEM technology. Four case studies are included to demonstrate the ability of the MobileMT data to aid in gold exploration programs, with particular emphasis on the system's ability to image the deeper geoelectrical environment, thus exploring not only the location of mineralization itself, where petrophysics might be not favourable, but also on the deep structures and related processes controlling the mineralization. A wider depth range of exploration is facilitating an overall improved understanding of the geology and development of a more accurate exploration model.

Key words: airborne geophysics, electromagnetics, gold, natural fields.

INTRODUCTION

Airborne electromagnetic systems which make use of controlled source primary field transmitters are limited in terms of their depth of investigation. This is particularly problematic in conductive environments, areas with conductive overburden, and in applications to exploration programs in rugged terrain, as relief contouring is critical for controlled source AEM systems and cannot be safely accomplished in such settings. "Passive" AEM methods, which exploit naturally occurring and varying electromagnetic (EM) fields (based on magnetotelluric and magnetovariational principles) overcome these limitations (Prikhodko et al., 2022). Another inherent advantage of the natural field EM method is its sensitivity to resistivity differentiations in a broad range, including thousands and tens of thousands of ohm-m's. Four examples from gold exploration programs are presented to demonstrate the performance of the MobileMT technology, the latest generation of airborne natural field EM technology. The MobileMT surveys were performed over the Kainantu deposit in Papua New Guinea with epithermal Au telluride veins and Au, Cu, Ag sulphide veins; the Thor epithermal Au, Ag, Pb, Zn, Cu system in Southeast British Colombia (Canada) with several known deposits, as well as newly discovered deposits; the Thorn project (Trapper Target) with Au, Cu, Ag epithermal mineralization in northwestern British Colombia; and the southern Tien Shan metallogenic belt (Central Asia) with orogenic giant gold deposits. All of these examples demonstrate the importance of EM imaging over a wide depth range for understanding the geological situation, developing an exploration model, and finding mineralization controlling structures.

METHOD AND RESULTS

Airborne electromagnetic survey techniques

The MobileMT system was used for the airborne EM surveys in all four gold exploration programs. The passive field measurement system consists of two main parts (Figure 1):

1) a three-component towed-bird receiver that measures variations in the magnetic field;

2) a stationary ground base station that measures horizontal components of the electric field and consists of independent signal and reference channels to provide denoised and bias free data.

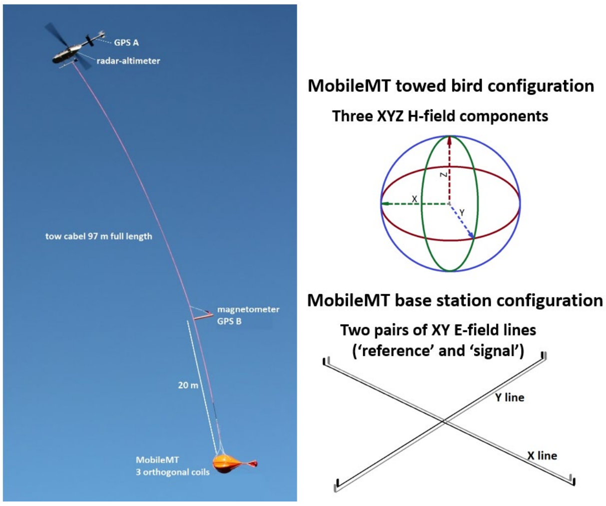

Figure 1. MobileMT system configuration

The technical details of the system and the data processing involved in the natural field EM method are described by Bagrianski et al. (2019), and Prikhodko et al. (2022).

Depending on the natural EM signal during the surveys, apparent conductivity data for a number of frequency channels, in the range of 26 Hz – 27 kHz, is extracted and processed for geoelectrical mapping. Inversions of the data are performed to convert the frequency-apparent conductivity data, output from the MobileMT system, into easier to interpret resistivity-depth data. For the surveys presented in the current study, the number of frequencies for which data was extracted, as well as the number of these frequencies used in the corresponding inversions is as follows:

- 22 frequency windows extracted; 14 of them in the range 26-534 Hz, were used for the Thor project;
- 17 frequency windows extracted; 12 of them in the range 26-387 Hz, were used for the Thorn project;
- 12 frequency windows extracted; 10 of them in the range 28-323 Hz, were used for the Tien Shan project;
- 13 frequency windows extracted; 9 of them in the range 27-256 Hz, were used for the Kainantu project.

Gold bearing structures mapping case studies

The following examples present the results of four MobileMT surveys operated by Expert Geophysics Limited, which were integrated into gold exploration programs in different regions worldwide (Canada, Papua New Guinea, and Central Asia - Kyrgyzstan).

Central Asia, Tien Shan (Orogenic gold)

The Tien Shan structure hosts a number of giant gold deposits including Kumtor, Muruntau, Zharmitan, Kokpetas, Jilau and others (Yakobchuk, 2005). The orogenic gold of the Kumtor deposit is on the mesozonal intrusive-related mineralization level at paleodepths on the order of 5 km (Figure 2) and occurs where the Vendian sediments have been hydrothermally altered and mineralized (Jancovic et al., 2021).

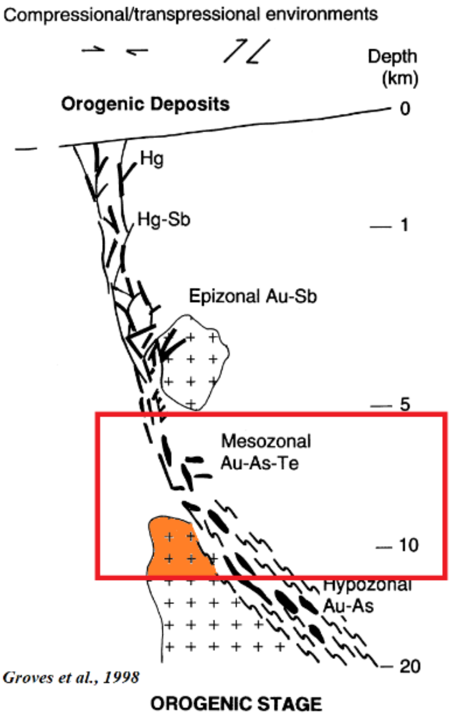

Figure 2. Conceptual diagram of a mineral system model for orogenic-gold deposits (after Groves et al., 1998) with the outlined paleo level of the Kumtor deposit

Near the end of 2019, an airborne MobileMT survey was conducted across the 440 km² area of the entire Kumtor Trend and included extensions beyond concession boundaries (Jancovic et al., 2021). The low resistivity zone on the map (Figure 3) reflects altered Vendian metasediments that extend over the entire belt and contain known gold deposits. Gold is associated with quartz-sulphide rocks (pyrite, galena, and chalcopyrite) and siliceous rocks along a contact of altered metasandstone of the Kashkasuu Formation and dolomitic siliceous Vendian rocks (Jancovic et al., 2021).

The MobileMT data were inverted, and the corresponding resistivity sections along two lines are presented (Figure 4) showing a link between the zone containing altered metasediments and a dome-like, deep-seated conductive structure which can be interpreted as a reduced intrusion, or an alteration zone above it.

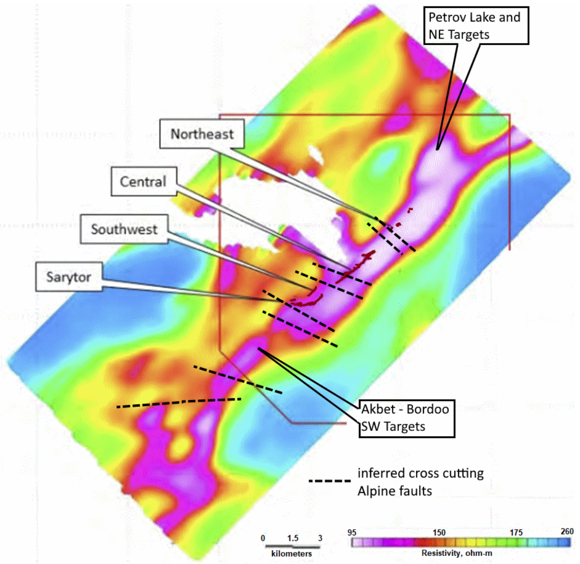

Figure 3. Map of electrical resistivity at a depth of 250 m modelled from MobileMT data with known deposits and mineralized zones.

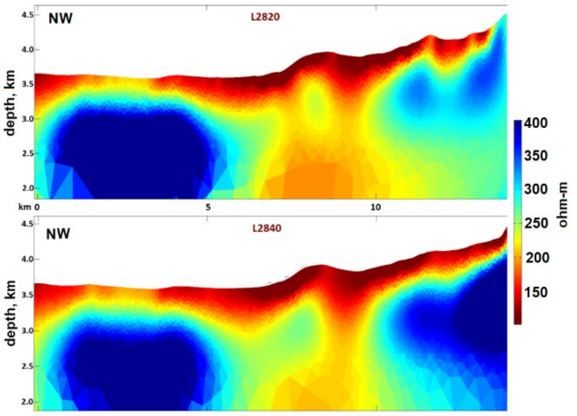

Figure 4. Resistivity sections along two lines (200 m apart) crossing the Akbet-Bordoo SW Targets from NW to SE

PNG, Kainantu (epithermal gold)

The Kainantu Gold Project is situated within what is known as the New Guinea Thrust Belt, a stretch of terrain which contains high mineralization of gold, silver and copper (epithermal and potentially related porphyry style mineralization). The thrust belt is composed of Late Miocene, sub-horizontal, shallowly north-dipping, thrust sheets of regionally metamorphosed Triassic to Eocene fine-grained sedimentary and minor volcanic rocks. During the middle Miocene, siliclastic sediments, carbonates and volcanic rocks were deposited. Thrusting began during the middle Miocene, which was accompanied by middle Miocene intrusions (Rogerson et al., 1987).

An area of 186 km^2 was covered by the MobileMT survey. The map of the apparent conductivity at 86 Hz (Figure 5) outlines only a part of the survey area with known deposits. Mineralization in the Kainantu District includes gold, silver and copper occurring in low sulphidation quartz-Au telluride veins, sulphide Au-Cu-Ag veins of Intrusion Related Gold Copper affinity, less explored porphyry Cu-Au-Mo systems, Au-base metal skarns and alluvial Au (Fleming, 2020).

The resistivity section along the line 2600 crossing the known vein deposit is shown below the conductivity map (Figure 5). The EM inverted data presented in the section recovers Irumafimpa-Kora, Mati, and potentially Aracompa vein systems. As the resistivity image shows, the mineralized vein systems are related to a generic deep source. The overall conductive environment and rugged relief severely limits the capabilities of using airborne EM methods with controlled sources in the region, whereas the airborne EM technology based on natural fields is effective.

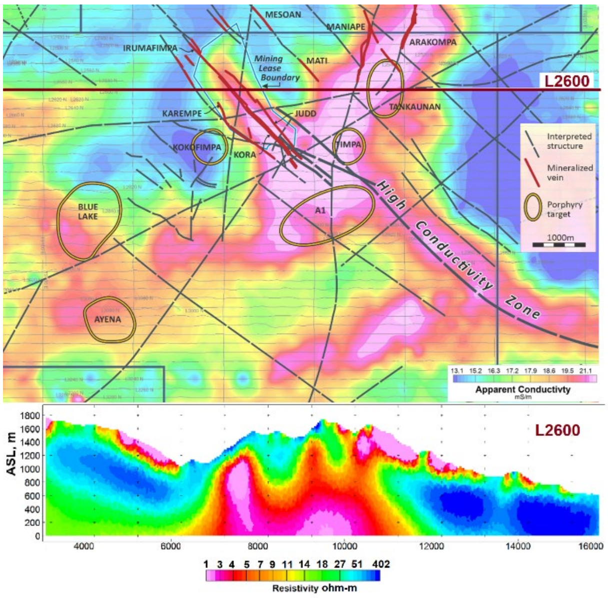

Figure 5. Top - Apparent Conductivity map over the Kainantu Mine area (K92 Mining Inc.) and mineralized vein field; Bottom – MobileMT resistivity section along the line L2600

British Columbia, Thorn Project (epithermal gold)

The Thorn project in Northwestern BC (Canada) includes an epithermal to gold-porphyry system with evidence for low-sulphidation and high-sulphidation overprints. The Trapper Target, specifically, is considered as a deep-rooted multi-phase gold porphyry system (Brixton Metals, 2021).

The apparent conductivity data corresponded to a comparatively low frequency (68 Hz), which is related to deep horizons, has very strong correlation with geochemical gold anomalies in the area (Figure 6).

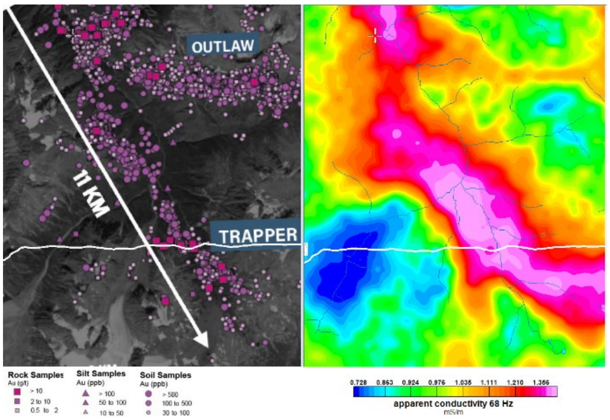

Figure 6. Left – gold high-grade geochemical samples (Brixton Metals); Right – MobileMT apparent conductivity 68 Hz map

The results of inversion of the MobileMT data are shown for one survey line in the form of a vertical cross-section (Figure 7). Indicated on the figure are the locations of a gold discovery in outcrop on the surface, and in the drillhole over a conductive subvertical zone with a deep-seated dome structure underneath. Although the known mineralization occurrences in this case are located near surface, the wide range of depth (~ 2km imaged) over which the MobileMT apparent conductivity can provide the geoelectrical picture provides greater insight in terms of the controlling structures and processes that are responsible for the observed distribution of mineralization. The discovered gold mineralization is hosted within iron carbonate altered volcanic rocks.

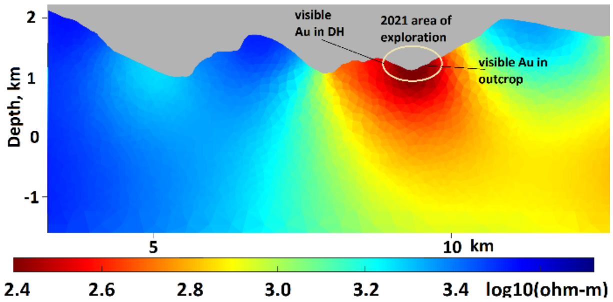

Figure 7. MobileMT resistivity section across the Trapper Target (white line in Figure 6)

British Columbia, Thor Project (epithermal gold)

The Thor Project area in Southeastern BC (Canada) includes five mineralized zones discovered during the past 120 years. Some of these deposits were historically mined. The area is located at the northern end of the Kootenay arc, an arcuate, north to northwest trending belt of Paleozoic and Mesozoic strata (McDonough, 2013). All known epithermal gold deposits are located within the Thor Fault Zone (Figure 8).

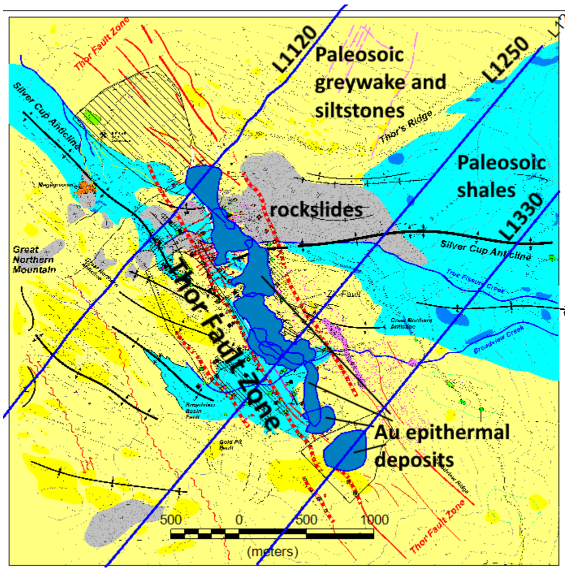

Figure 8. Schematic geological map of the Thor epithermal gold system (Taranis Resources Inc.)

The resistivity sections along lines crossing three known deposits are shown in the Figure 9 – 44Lower Deposit (L1120), newly discovered Thunder Zone (L1250), and the high-grade deposit Broadview (L1330).

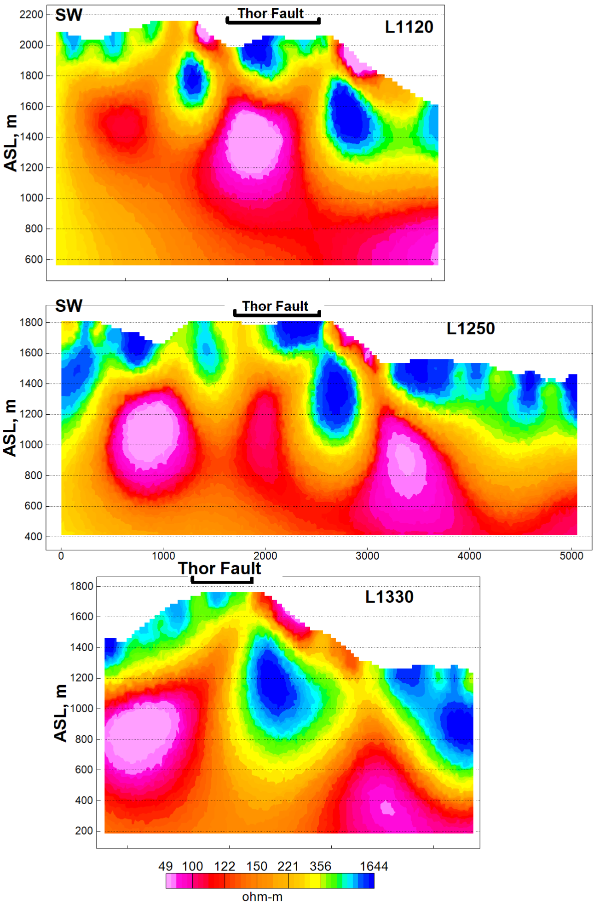

Figure 9. MobileMT resistivity sections along the lines presented in plan view in the Fig.8

Geologists (Taranis Resources Inc.) have noted that the rocks overlying the epithermal zones usually are incredibly silicified – and it is always Broadview Formation (Greywackes). In the resistivity sections, we can see the highly resistive zones overlying conductive zones where the epithermal deposits are located. Most likely, the highly resistive zones reflect the silicification process.

CONCLUSIONS

One of the main advantages of the passive airborne EM method with the wide frequency band is the broad range of depth of investigation, which spans from relatively near-surface to more than 1 km. The depth of investigation is offering a more complete picture of the distribution of electric properties. The examples of exploration for gold mineralization presented from different regions of the world demonstrate the effectiveness of mapping in a broad depth range for better understanding of the geology, refining an exploration model, and delineating the positions of structures controlling mineralization.

ACKNOWLEDGMENTS

Expert Geophysics Limited would like to acknowledge their clients for providing permission to publish results of the surveys included in this work. The authors are grateful to operators (Kobus de Beer, Patrick Yee, Wbeimar Guevara, Matthew Johnston) and geophysical data processors (Julian Boada, Farzad Gholamian) for their cooperation during the fieldwork, data quality control, and data processing.

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