Detecting and recovering porphyry and epithermal mineralization systems with broadband natural field airborne EM (on examples of MobileMT data)

Alexander Prikhodko, Expert Geophysics Limited*

Summary

Airborne geophysics exploiting natural electromagnetic fields enhances the exploration capabilities and overcomes limitations of commonly used inductive airborne systems with controlled primary field sources. The latest development in the airborne natural EM fields or passive method (AFMAG), MobileMT system, provides a depth of investigation from the near-surface to over 1 km and detects resistivity variations across a wide range, encompassing conductive targets and structures as well as highly resistive ones. The high-end resistivity range is typically beyond the detectability of time-domain systems with controlled primary field sources. By utilizing three orthogonal inductive coils as a receiver, the the MobileMT system is sensitive to geological formations of any arbitrary geometry. Porphyry and epithermal mineralization systems develop in conditions of active subduction and they are characterized by a wide variety of structural, lithological, and alteration patterns, which, at least partially, can be depicted in geoelectrical images. We conducted field investigations on several known porphyry and epithermal mineralization systems in different geological settings with different geoelectrical patterns. These field examples demonstrate the effectiveness of resistivity mapping and sounding using the MobileMT system.

Introduction

Petrophysical and, specifically, geoelectrical models for porphyry and epithermal systems lack standardization and unification. Various factors, including differences in host rock lithology and composition, the extent and intensity of specific alteration processes, the development of fracture and fault systems, subsequent infiltrations, post-ore tectonic events, and the current level of erosion influence the resistivity pattern of porphyry and epithermal systems. Regardless of the complexity of porphyry systems and related possible exploration challenges, resistivity methods are considered to be one of effective geophysical tools in the exploration of porphyry prospective areas (Mitchinson et al., 2013).

MobileMT technology, an airborne electromagnetic system utilizing natural electromagnetic fields (Sattel et al., 2019; Prikhodko et al., 2022), is capable of recovering porphyry and epithermal mineralization systems, or at least their specific structural patterns. MobileMT has a depth of investigation beginning from near-surface up to 1-2.5 km, significantly exceeding active-source airborne EM systems in any geoelectrical conditions. Due to technical solutions introduced in the technology, MobileMT is sensitive to resistivity differentiations in a wide range and to geoelectrical boundaries of any direction. The detectability features of the MobileMT technology make it especially useful in dealing with petrophysically widely varying porphyry and epithermal mineral systems.

The case studies from MobileMT surveys are presented over areas with known porphyry and epithermal mineralization systems and mineralization-controlling structures. The recovered resistivity-depth images are compared with actual geology or conceptual geological models of the mineralization systems, which illustrate the system's capabilities in imaging the mineralization systems and their diverse geometries and wide resistivity range.

MobileMT technique

The MobileMT measuring system includes two main parts (Figure 1):

- Three orthogonal dB/dT inductive coils fixed rigidly to each other (Figure 1b) in a drop-shaped shell towed below the helicopter. Variations of the magnetic field (H-field) measured by the inductive receiver are recorded digitally in an acquisition system placed inside a helicopter.
- Two pairs of independent grounded orthogonal electric lines positioned a few meters apart (Figure 1a) for measuring ‘main’ and ‘reference’ variations of the electric field (E-field).

The combination of magnetic (H) and electric (E) fields variations allows the use of the concept of the admittance tensor introduced by Thomas Cantwell in 1960 as Y = H/E (Cantwell, 1960; Jones, 2017) and, ultimately, the calculation of apparent conductivities corresponding to different frequency bands. The “apparent conductivity – frequency” data is inverted with 2.5D algorithm into “resistivity-depth” information as standard deliverables.

The electromagnetic field variations are measured in the 26 Hz – 21 kHz frequency range which provides a covering of near-surface and in-depth geology.

This airborne electromagnetic technology offers several advantages, such as: 1) its ability to investigate a wide depth range (from the near-surface to one-two kilometers and deeper if a geological environment is highly resistive): 2) sensitivity to geoelectrical boundaries in any direction (from horizontal to vertical): 3) sensitivity across a broad range of resistivities and 4) high spatial and depth resolution.

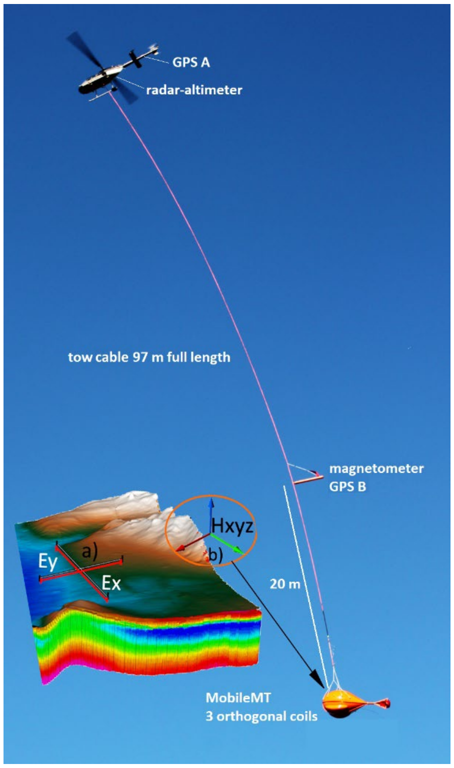


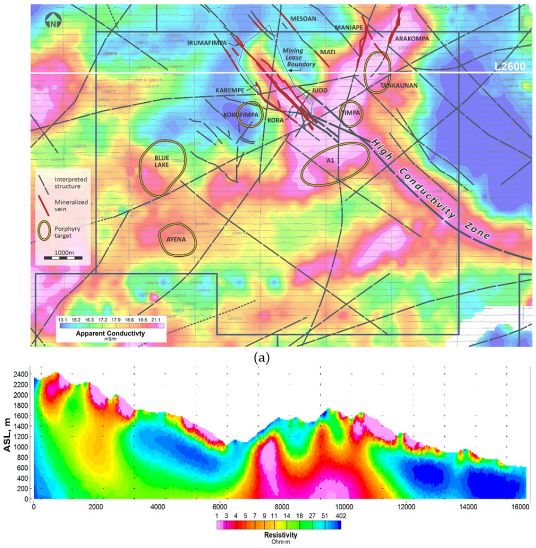
Figure 1: The MobileMT system in survey configuration. a) Schematic of a base station, that includes two pairs of independent grounded orthogonal electric lines in the same position, b) shows a schematic of three orthogonal dB/dT inductive coils.

Case Studies

Kainantu Gold Mine (PNG)

The Kainantu property ("K92 Mining") is located within the New Guinea Thrust Belt, close to its northern contact with the Finisterre Terrane (Kainantu mine, 2022). The contact is marked by the northwest trending Ramu-Markham Fault, a major suture zone that marks the northern margin of the Australian Craton. The belt is characterized by a number of north-northeast trending fault zones that commonly host major ore deposits. Mineralization on the property includes Au, Ag and Cu occurring in low sulphidation epithermal Au-telluride veins, Au-Cu-Ag sulphide veins of Intrusion Related Gold Copper ("IRGC") affinity, less explored porphyry Cu-Au systems and alluvial gold. The property encompasses an epithermal vein field consisting of multiple known and highly prospective vein systems: Kora, Irumafimpa, Karempe, Judd, Kora South, Mati, Maniape and Arakompa.

The survey area is typified by rugged mountainous terrain with conductive overburden, which makes it very challenging for AEM surveys with controlled primary field sources. The MobileMT survey results show an excellent correlation between a known sulphidic Cu-Au vein field and conductive structures (Figure 2).



(a)

(b)

Figure 2: (a) MobileMT apparent conductivity color grid (86 Hz) with overlapped mineralized veins, structures and porphyry targets; (b) Resistivity-depth section along 2600 survey line (2D inversion).

Recently discovered porphyry mineralization in the area (Blue Lake) is correlated with high resistivity in depth under the conductive argillic lithocap (Figure 3).

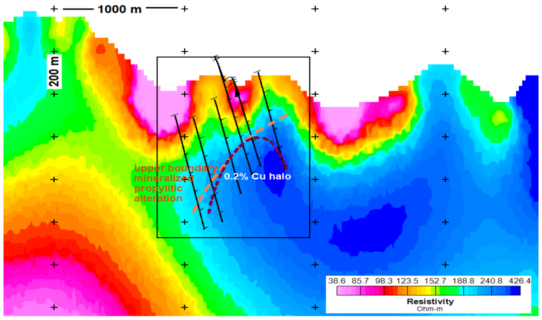


Figure 3: MobileMT resistivity section through Blue Lake porphyry, with projected DHs to the survey line

The case study shows that mineralization of differing types within the same area displays different petrophysical traits and can be recovered through the use of the airborne natural field technology.

Panantza and San Carlos porphyries (Ecuador)

The porphyry copper deposits of the Corriente Copper-Gold Belt are associated with late porphyritic intrusive phases of the Late Jurassic calc-alkaline batholiths of the Cordillera Real and sub-Andean Cordillera del Condor (Drobe et al., 2007). Potassic alteration dominates in the mineralised granite and leucogranite host rocks, and the pre- and syn-mineral porphyries. The potassic zone occurs within a broader 2 x 1.5 km propylitic zone, which has a narrow, 500 to 1000 m wide arm that extends for a further 2 km to the north (outlined by green area in Figure 4). Argillic alteration occurs within the supergene zone and extends downward, overprinting the potassic alteration along structures (Drobe et al., 2007).
The MobileMT test survey over the deposits showed a good correlation between conductive zones and the deposits' contours (Figure 4, Figure 5).

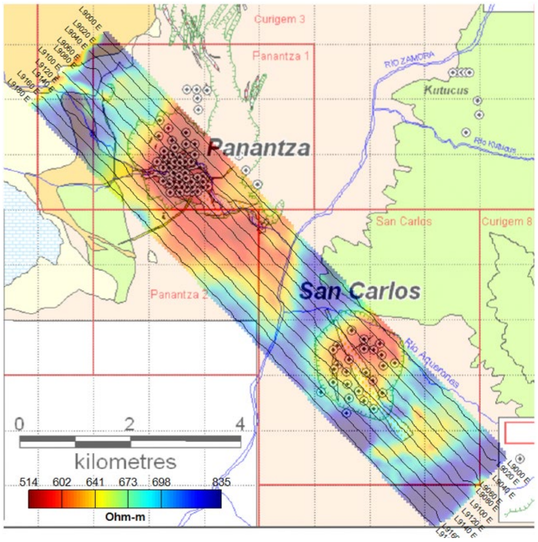


Figure 4: MobileMT resistivity depth slice over Panantza and San Carlos porphyry deposits

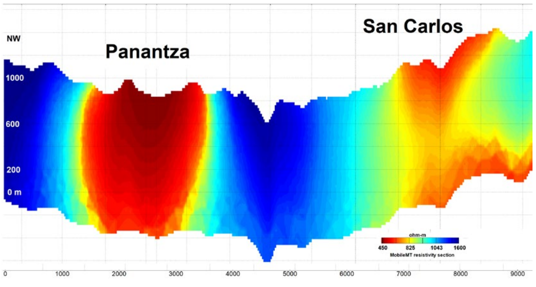


Figure 5: MobileMT resistivity sections over Panantza and San Carlos porphyry deposits (L9080 in Fig.4)

Epithermal Dukat Ag-Au deposit (Far East of Russia)

The Omsukchan mining district with epithermal silver-base-metal deposits (Dukat, Lunny, Arylah) and many occurrences is confined to the rift-related volcanic trough.
Main elements of the Dukat deposit that govern the ore bodies' structure are subvertical zones consisting of systems of sub-parallel shear cracks, zones of mylonite along faults, veins controlled by faults, and individual large fractures (Levitan, 2008).

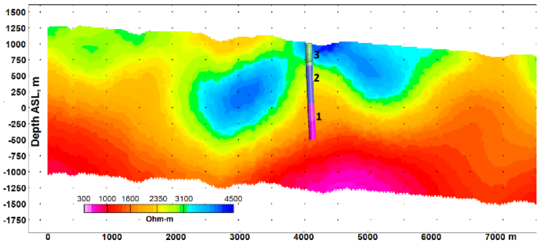


Figure 6: MobileMT resistivity section with a deep drillhole position in the Dukat Ore Field (1- granite and granodiorite intrusive dome, 2-rhyolite lavas, ignimbrites and tuffs, 3-andesite lavas intercalated with black argillites)

The MobileMT survey over the area revealed buried deep dome structures; subvertical comparatively conductive zones interpreted as fluid transport channels from the upper contact of the deep magmatic bodies to the near-surface host rocks followed by alteration and ore zones.

Epithermal polymetallic deposits in Kendyktas Ridge (Southern Kazakhstan)

Copper, copper-gold, and copper-molybdenum deposits in the Kendyktas Ridge (Central Asian Ordovician magmatic arc) in south-central Kazakhstan are commonly associated with stockwork style and veins (Zientek et al., 2014). Jaisan and Ungurli are typical deposits in the region. Approximately half of the mineralization in the deposits is associated with metasomatically altered granitoids, and half occurs as quartz-chalcopyrite and quartz-calcite-chalcopyrite veins. The known deposits in the region are positioned over subalkaline intrusives of Devonian age (Zhadrinsky intrusive complex), which underly the older late Ordovician granites in the areas of the Ungurli ore field and the Jaisan deposit. The Devonian subalkaline intrusive rocks were defined as highly resistive from the results of historical IP surveys in the region. The results of the MobileMT survey show electrically resistive dome structures at depth, which are interpreted as intrusives of the Zhadrinsky complex and resistive "vents" resembling a vertical pipe that coincides with the position of the known ore zones of the Ungurli Cu-Mo-Au deposit (Figure 7).

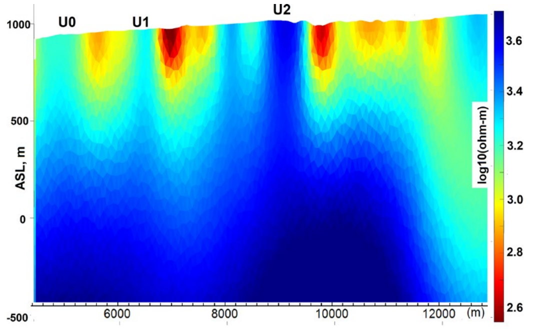


Figure 7. Resistivity section along a line crossing known ore zones (U0, U1, U2) of the epithermal deposit Ungurli in the area of Kondyktas Ridge

Conclusions

Advancements in natural field airborne electromagnetic techniques have resulted in improved exploration abilities. The provided case studies illustrate the technology's capacity to investigate depths from near-surface up to more than 1 km and highlight the capability of the airborne EM technology to identify geoelectrical boundaries with diverse geometries and detect variations in resistivity across a broad range. The case studies illustrate that there are no universally established geoelectrical patterns for porphyry and epithermal mineralization systems, except when considering their morphological aspects in plan and section views. The absolute resistivity values and their ratios between targeting structures and host rocks can vary significantly (as shown in Table 1). Consequently, they cannot serve as reliable references when characterizing porphyry and epithermal systems.

Table 1

Deposit name	Target resistivity, ohm-m	Background resistivity, ohm-m
Kainantu epithermal high sulfidation	1-15	100-400
Kainantu porphyry	**450**	**<100**
Panantza porphyry	485	1800
San-Carlos porphyry	750	1500
Dukat epithermal	300-1500	>2500
Jaisan-Unguli epithermal	**2000-6500**	**<1000**

Understanding the geological and structural models of mineralization systems in an explored region is crucial for geoelectrical image interpretation for exploration and targeting purposes. By integrating geological knowledge with geoelectrical imaging, exploratory efforts become more focused and efficient, increasing the likelihood of successful mineral discovery.

References

Cantwell, T., 1960, Detection and analysis of low frequency magnetotelluric signals: PhD. thesis, Massachusetts Institute of Technology.

Drobe, J., Hoffert, J., Fong, R., Haile, J.P. and Rokosh, J., 2007 - Preliminary assessment report, Panantza and San Carlos copper project, Morona-Santiago, Ecuador; 43-101 Technical Report prepared for Corriente Resources Inc., 247p.

Levitan, G., 2008, Gold Deposits of the CIS: Xlibris, USA.

Panantza and San Carlos copper project, Morona-Santiago, Ecuador; A NI 43-101 Technical Report prepared for Corriente Resources Inc., 247p

Jones, A.G., 2017, Magnetotellurics: Status Quo and Quo Vadimus, in Tschirhart, V., and Thomas, M.D., eds., Proceedings of Exploration 17: Sixth decennial international conference on mineral exploration, 139–158.

Kainantu Mine. Available online: https://k92mining.com/kainantu-mine/ (accessed on 4 April 2022).

Mitchinson, D.E., Enkin, R.J. and Hart , C.J.R. , 2013, Linking porphyry deposit geology to geophysics via physical properties: adding value to Geoscience BC geophysical data: Geoscience BC Report 2013-14.

Prikhodko, A., A. Bagrianski, P. Kuzmin, and A. Sirohey, 2022, Natural field airborne electromagnetics – history of development and current exploration capabilities: Minerals, 12(5), 583, 1-16, doi: 10.3390/min12050583.

Sattel, D.; K. Witherly, and V. Kaminski, 2019, A brief analysis of MobileMT data: 82nd Society of Exploration Geophysicists International Exposition and Annual Meeting, SEG, Proceedings, 2138–2142, doi: 10.1190/segam2019-3215437.1

Zientek, M., J. Hammarstrom, and K. Johnson, 2014, Porphyry copper assessment of Western Central Asia: USGS scientific investigations report 2010-5090-N, doi: 10.3133/sir20105090N.