MobileMT Field Performance over El Teniente and La Huifa porphyry systems (case study)

full paper

Introduction

Airborne natural-source electromagnetic (EM) methods are increasingly used in mineral exploration to map subsurface resistivity, particularly in rugged terrain, areas with limited ground access, and structurally complex settings. Despite their growing adoption, direct field comparisons between passive airborne systems remain uncommon. Early airborne AFMAG development by Dr. Petr Kuzmin [1] and collaborators introduced three-component magnetic sensing, MT-style spectral processing, and transfer-function estimation in an airborne configuration, forming the basis for the ZTEM one-component (tipper) system and motivating later fully rotationally invariant passive systems. MobileMT represents the culmination of these developments, recovering resistivity from frequency-dependent relationships between naturally varying magnetic and electric fields. MobileMT records three-component magnetic-field variations in the air and uses a stationary ground electric-field reference to estimate broadband admittance tensors and rotationally invariant responses. Apparent conductivities are computed in multiple narrow frequency windows (up to 30) spanning 26–21,000 Hz. In contrast, ZTEM derives a unitless tipper response from the vertical magnetic component over a narrower band (25–600 Hz), typically divided into no more than six frequency windows.

This study presents a direct system-level, field-based comparison of MobileMT and ZTEM for porphyry exploration using coincident survey data acquired over the El Teniente and La Huifa porphyry deposits in central Chile. The two survey areas provide contrasting noise conditions that test practical performance. The objective is to compare plan-view coherence and the interpretability of resistivity–depth sections produced using consistent, non-constrained inversion workflows.

Results show that MobileMT provides more coherent and interpretable resistivity imaging than tipper-only airborne AFMAG over both deposits. MobileMT retains coherent responses and resolves key porphyry features, including a resistive core, conductive alteration zones, and subvertical conductive structures.

Comparative field performance of MobileMT and ZTEM systems

Although several studies have compared airborne AFMAG systems in specific geoelectrical settings and flat-relief environments such as the Athabasca Basin [2,3], the relative performance of MobileMT and ZTEM in geologically complex mineral systems and rugged relief conditions has not been previously evaluated using coincident survey data and consistent non-constrained inversion workflows.

This section evaluates the relative field performance of MobileMT (Expert Geophysics Limited, 2018) and ZTEM (Geotech Ltd., 2006), using survey results from the El Teniente and La Huifa porphyry systems in central Chile.

Systems-level considerations

MobileMT (total-field, tensor-based):

- Measures three orthogonal magnetic-field variation components in the air and uses a stationary electric-field reference on the ground. The system is sensitive to any complexity of geoelectrical structures.
- Estimates MT-style admittance tensors and rotationally invariant responses across many narrow frequency windows (typically 10–24 usable windows, depending on EM natural signal conditions – up to 30 windows). More usable frequency windows improve in-depth resolution and stabilize the inversion.
- Broad nominal bandwidth (~26-21,000 Hz) supports sensitivity to both shallow and deeper structures.

ZTEM (tipper-based):

- Uses one vertical magnetic component to compute a tipper response.
- Primarily sensitive to lateral conductivity contrasts and structural gradients; it does not recover absolute resistivity and can be less responsive to compact 3D bodies [4].
- Provides fewer usable frequency windows (maximum six over ~25–600 Hz, depending on conditions).
- Workflow involves tilt-related corrections with assumptions that are difficult to validate in rugged terrain [5].

Brief Geology Description

El Teniente, located in the Andes of central Chile, is the world's largest known copper-molybdenum deposit, with a resource scale >100 Mt Cu contained [6]. A flat-lying sequence of arc-related volcanic and volcanoclastic andesitic rocks hosts El Teniente deposit. A series of felsic to intermediate intrusions was emplaced into the host rocks, followed by porphyritic phases. Dacite pipes and a dacite porphyry dike are temporally and spatially related to Cu and Mo-bearing veins and extensive potassic alteration [7]. The Braden Pipe is a large, late- to post-mineralization breccia body with low copper grades, located at the center of the deposit. It forms an inverted cone roughly 1,200 m across at the surface, bounded by inward-dipping walls that range from about 60° to 80° [7]. Important for the deposit formation, generally subvertical N-S, NE-SW and NW-SE crustal structures intersect at the deposit, and the actual depth to which copper mineralization extends is unknown [7].

Another porphyry deposit, La Huifa, a quartz-diorite porphyry, is associated with hydrothermal breccias and alteration zones and is located 4 km northeast of the El Teniente deposit [7]. A schematic geological map is shown in Figure 1, along with MobileMT and ZTEM survey lines that cross the deposits.

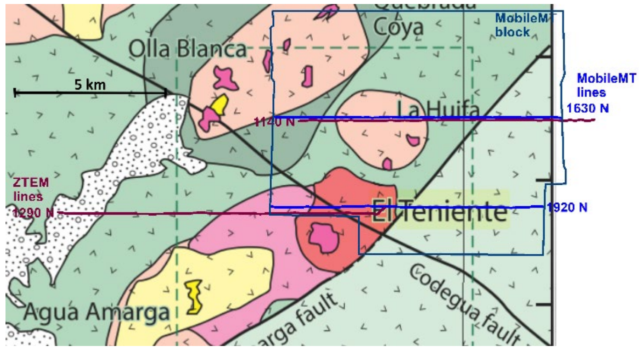

Figure 1. *Simplified geological map of the El Teniente district (after [8]) with MobileMT (blue) and ZTEM (red) survey lines superimposed over the El Teniente and La Huifa deposits.*

Description and analysis of the airborne passive EM systems' performance

Below is a direct comparison between the total-field broadband admittance MobileMT data and the tipper ZTEM data over the deposits in plan view and in the inverted resistivity-depth images. Both datasets were inverted in 2D without geological constraints.

Figure 2 shows the ZTEM in-phase total divergence grid (75 Hz) [9], illustrating that the western part of the El Teniente area is significantly contaminated by nearby powerlines. The ZTEM response over the deposit is dominated by short-wavelength noise and lateral striping, which obscures the conductive signature expected from porphyry feeder systems and alteration zones. Although a subtle anomaly is visible over La Huifa, its low contrast against a highly textured background prevents reliable interpretation or structural delineation.

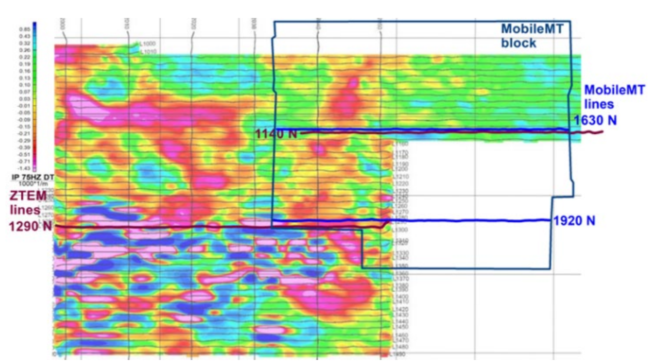

Figure 2. *ZTEM In-Phase Total Divergence 75 Hz color grid (from [9]) with MobileMT (blue) and ZTEM (red) survey lines crossing El Teniente and La Huifa deposits*

In contrast, the MobileMT apparent-conductivity grid at a comparable frequency (86 Hz [10]; Figure 3) presents a coherent, geologically consistent spatial pattern. The northern portion of the El Teniente deposit, covered by the MobileMT survey block, exhibits a distinct conductive feature that is sharply differentiated from the surrounding host rocks. At La Huifa, MobileMT outlines a continuous NW–SE–aligned conductive trend, revealing the structural corridor that hosts the porphyry intrusion and associated breccia bodies. These plan-view results highlight the superior noise immunity (close to El Teniente) and anomaly focus provided by MobileMT.

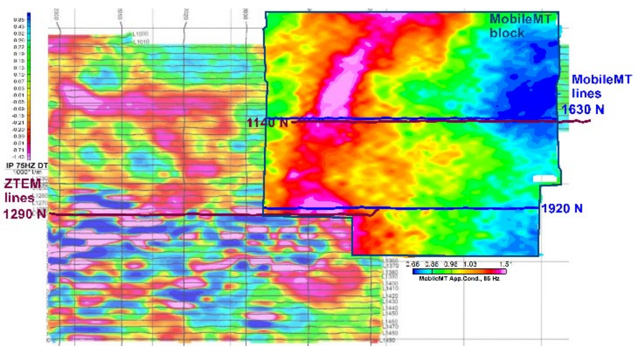

Figure 3. *ZTEM In-Phase Total Divergence 75 Hz color grid (from [9]) and overlain MobileMT apparent conductivity grid (outlined), 86 Hz (from [10]), with survey lines crossing El Teniente and La Huifa deposits.*

Resistivity-depth sections along MobileMT (L1920, [10]) and ZTEM (L1290, [9]) lines above the El Teniente deposit are shown in Figure 4. Due to powerline interference, only three ZTEM frequencies were usable for inversion. The resulting ZTEM inversion provided in [9] resolves a shallow, laterally extensive conductor but fails to reproduce the vertical zonation, subvertical conduits, or deeper conductive roots typical of porphyry systems.

The MobileMT inversion, based on ten frequencies spanning a wide bandwidth, produces a robust and geologically consistent model. A central resistive zone coincides with the mapped potassic core, flanked by conductive alteration halos and subvertical conductive structures that mirror the known geometry of mineralized feeder zones. As shown, the width of the resistive core in the MobileMT section (Figure 4) corresponds closely to geological constraints (according to the geological section in Figure 5, ~800 m), and the conductive zones match the distribution of >0.5% Cu grades. These results indicate greater depth penetration of the MobileMT system, and its structural resolution is superior to ZTEM.

The La Huifa deposit lies roughly 4 km northeast of El Teniente and is also distant from the power lines (Figure 1 and Figure 2). Figure 6 presents data profiles and resistivity sections along ZTEM L1140 [9] and MobileMT L1630 [10], which cross the La Huifa deposit along nearly coincident paths. ZTEM provides six frequencies between 25–600 Hz, yet the inversion shows a horizontal, comparatively weakly expressed conductor insufficient to characterize the deposit's structural environment and vertical extent. MobileMT, utilizing fifteen frequencies between 27 and 1124 Hz, recovers a resistivity pattern analogous to that observed at El Teniente and typical of porphyry systems. The model shows a resistive core interpreted as the potassic core, surrounded by conductive alteration zones and vertically continuous structures. The MobileMT response at La Huifa is laterally coherent and forms part of the broader NW–SE conductive trend identified in plan view, highlighting both the deposit and its controlling structural framework.

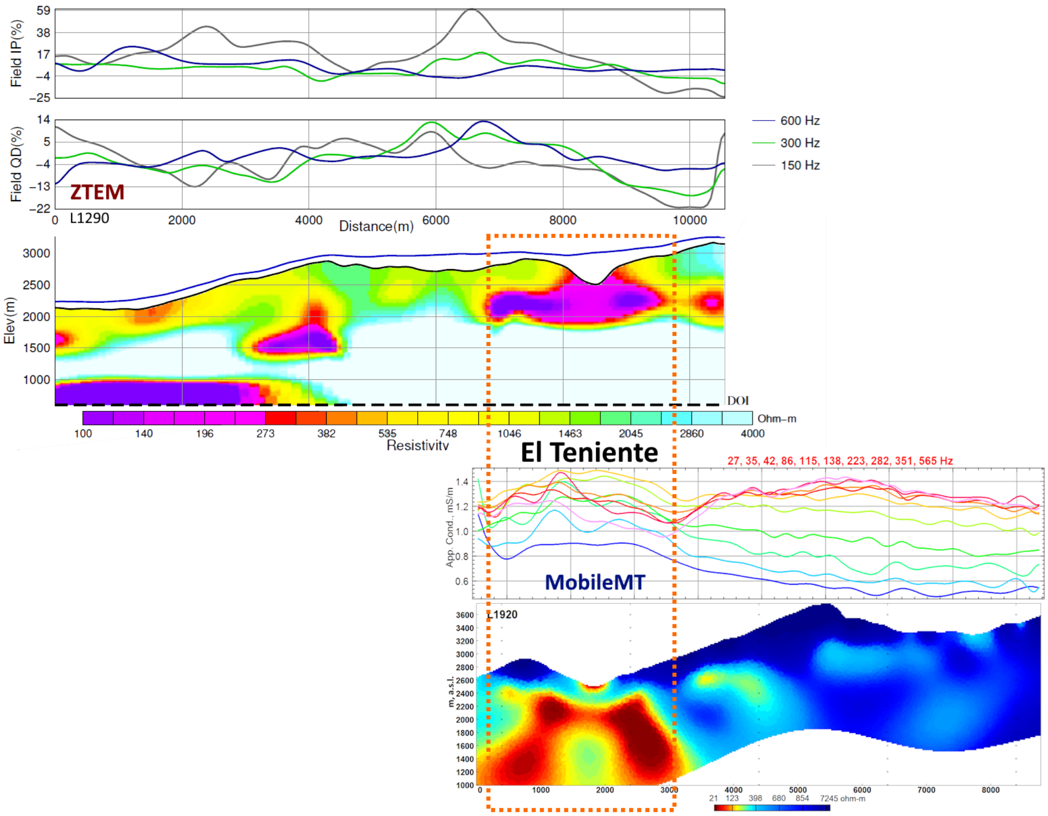

Figure 4. *ZTEM (L1290, [9]) and MobileMT (L1920, [10]) 2D resistivity-depth inversion sections over the El Teniente deposit (ZTEM: top; MobileMT: bottom).*

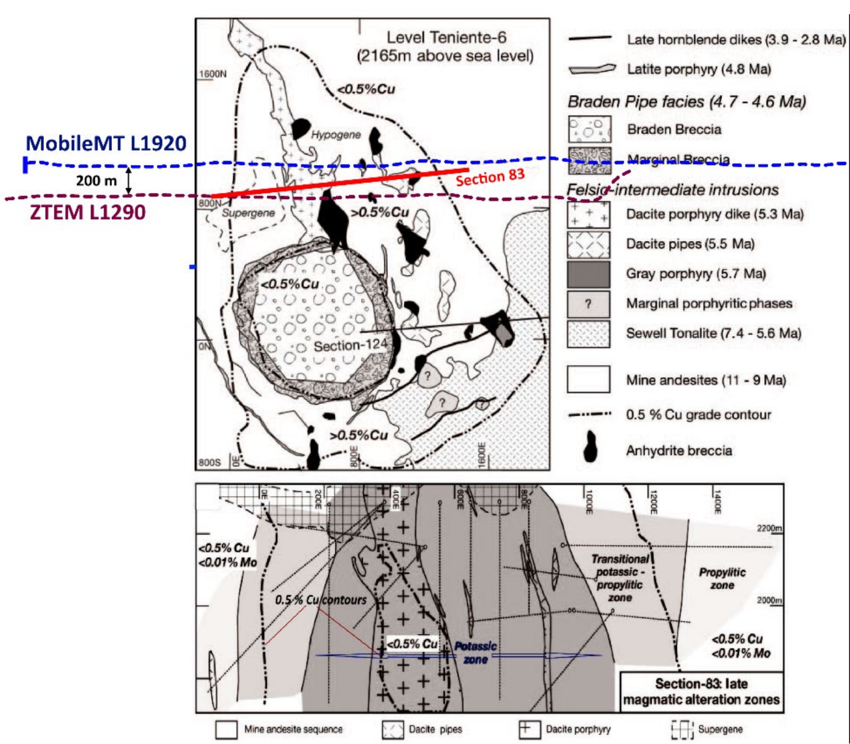

Figure 5. *Geological map of the El Teniente deposit at 2165 m asl with portions of the geophysical surveys lines crossing the deposit (dashed lines, top); and geological Section-83 (bottom), not in the same scale as the map (after [8]).*

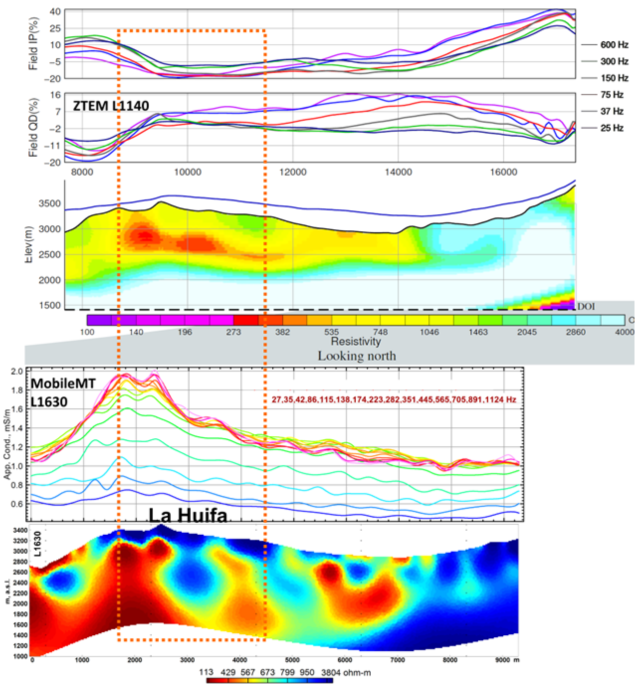

Figure 6. *ZTEM (L1140, [9]) and MobileMT (L1630, [10]) multi-frequency data profiles and 2D resistivity-depth inversion sections across the La Huifa porphyry deposit.*

Conclusions

Across both porphyry centers, MobileMT produces higher coherence and more geologically consistent resistivity-depth images than ZTEM. At El Teniente, powerline interference substantially restricts ZTEM usable bandwidth and degrades interpretability, while MobileMT retains coherent responses and resolves key porphyry-related features. At La Huifa, where cultural noise is minimal, MobileMT still provides clearer and more continuous structural and resistivity patterns, indicating that the observed performance difference is not explained by noise conditions alone.

The case study supports broadband, total-field, tensor-based MobileMT as a more robust approach than tipper-only airborne AFMAG for porphyry exploration in rugged and structurally complex settings.

Acknowledgments: Expert Geophysics Surveys Inc. acknowledges the significant contributions of its technical department, field crews, data-processing personnel, and geophysicists, whose efforts enabled the acquisition, quality control, and preparation of the datasets used in this study. The company also thanks Exploraciones Mineras Andinas S.A. for providing access to the geophysical survey reports and for granting permission to make the results public, which enabled the comparative analysis presented in this paper.

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