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Expanding the reserve base of operating mines: Insights from an airborne MobileMT survey in the Omsukchan depression, Russian Far East

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SUMMARY

In the frame of expanding the reserve base for the Omsukchan mining district, an airborne electromagnetic survey was carried out over and around the Dukat silver giant. The initially developed exploration concept was based on weakly investigated deep structures controlling the epithermal mineralization in the region.

The airborne electromagnetic technology, MobileMT, based on exploiting natural fields in the audio frequency range provided depth of investigation, in the geoelectrical environment, from near-surface up to, at least, 2.5 km. The areal resistivity mapping data over the regional trough structure provides valuable insights on deep dome structures and following subvertical feeding and transporting zones which control the silver-polymetallic mineralization.

The position of around 20 known deposits and occurrences was analysed in relation to numerically derived resistivity models. The results of the empirical analysis are used for identifying prospective zones for new discoveries.

Key words: airborne geophysics, epithermal mineralization, MobileMT, electromagnetics.

INTRODUCTION

The Cretaceous Okhotsk-Chukotka volcanic belt with associated volcanic arcs and related world-class gold-silver deposits belongs to the western part of the “Pacific Rim of Fire” (Corbett, 2013). Despite a more than 50-year history and well-exposed surface geology, the territory is under-explored in-depth (Sidorov et al., 2009). The Omsukchan mining district with epithermal silver-base-metal deposits (Dukat, Lunny, Arylah) and many occurrences is confined to the rift-related volcanic trough. The roots of the epithermal mineralization and their possible links to porphyry sources remain poorly studied and ambiguous (Sidorov et al., 2009).

Conducting the survey using MobileMT technology was chosen for several reasons – the system is sensitive to resistivity differentiations in a wide range, including a highly resistive background typical for the exploration area; depth of investigation exceeds capabilities of any airborne EM with controlled sources in several times; sensitivity to any direction of geoelectrical boundaries.

The airborne electromagnetic survey was deployed over 1,325 sq.km of the trough structure, with 200 meters line spacing, for the purpose of in-depth resistivity mapping to recover the mineralization controlling structures. The principal results of the airborne electromagnetic survey include identifying and mapping important epithermal mineralization formation structures: deep dome structures of the underlying mineralization granitoid batholiths; subvertical feeding, transporting mineralization solutions diatreme-similar structures; and caldera structures.

EXPLORATION AREA, METHOD AND RESULTS

Geological setting and exploration tasks

In the regional scale, the study area belongs to the Cretaceous Okhotsk-Chukotka volcanic-plutonic belt in the Russian Northeast. The belt extends more than 3000 km and hosts several gold-silver deposits, including large and world-class deposits, and thousands of occurrences (Sidorov et al., 2009). The exploration area lies within one of the belt’s lithotectonic zones, Omsukchan Graben – a rift-like trough formed in the Early Cretaceous period along a North-South fault system, and includes the Dukat silver-gold Ore Field, and other epithermal silver-gold deposits and occurrences. The framework of the graben-shaped depression (~150 km long) is intruded by numerous Early and Late Cretaceous granitoid polyphase stocks and plutons, porphyry, and dykes (Konstantinov, 2010). A number of known epithermal silver-gold deposits and occurrences form the Dukat ore field including the eponymous world’s third-largest silver deposit. Currently four deposits are under mining operations in the Polymetal’s Dukat hub with a predicted end-of-life of 2026.

Despite well studied surface geology of the area, many aspects of deep structures controlling the mineralization remain poorly investigated (Sidorov et al., 2009). The Dukat deposit area is spatially associated with an intrusive-volcanic dome structure surrounded by magmatic stocks and dykes forming a ring complex (Seltman et al., 2010). This is confirmed by numerous drill holes and sporadic deep drilling (1200-1500 m) in the frame of the ore field. 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). Finding other dome- and perhaps caldera-similar structures on the territory, as well as steeply dipping roots of the epithermal mineralization, may prompt further detailed exploration which may lead to new discoveries.

MobileMT airborne EM technology

To develop the exploration concept based on the deep structures, the MobileMT survey was carried out over the central part of the volcanic trough structure covering 1325 sq.km with 200 m line spacing. The line spacing was chosen based on the principle of a minimum of three lines crossing the target of interest.

The airborne MobileMT electromagnetic technology is based on exploiting natural electromagnetic fields in the audio-frequency range and relates to the evolutionary development of the AFMAG method (Bagrianski et al., 2019). Table 1 outlines four main advantages of the "passive" airborne EM technology and their corresponding technical solutions.

Table 1. Main MobileMT exploration advantages and technical features.

Exploration advantage	Technical solution
Depth of investigation from near surface to >2 km (for the Omsukchan project)	Accepted data for 16-20 frequency windows in the range 28-14,321 Hz
Sensitivity to any direction of geoelectric boundaries, from horizontal to vertical	3 orthogonal inductive coils in the air (H-field); 2 pairs perpendicular grounded electric lines (E-field)
Sensitivity to the absolute conductivities	Admittance data with the apparent conductivity output
Sensitivity to resistivity differentiations in the broad range of values, including in the highly resistive environment with poorly conductive features (in thousands Ohm-m)	Low system noise due to: - not required the bird tilting motion compensation; - base station signal/reference data (no signal bias problem); - high frequency data recording sampling – 74 kHz.

The listed MobileMT system advantages and preliminary forward modelling study of assumed geoelectrical scenarios facilitated the technology choice for the exploration program.

Survey results

An example of MobileMT data profiles and corresponding inverted resistivity section over the property are presented in Figure 1. The figure displays the processed apparent conductivity data from line 2420. Fitting the resistivity model to this data indicates a conductive underlying basement, usually including the most conductive dome structures, overlying resistive complex, and subvertical moderate-to-high conductive zones arising to the surface. Early Cretaceous over Triassic-Jurassic basement (molasse and shales) is intruded by Cretaceous multiphase diorite-granodiorite-granite plutons and covered by andesite and rhyolite lavas with younger subvolcanic facies (Seltman et al., 2010). The subvertical more conductive zones in the resistive volcanic rocks are interpreted as channels of ascending hydrothermal metal-bearing fluids. The position of almost all analysed significant ore occurrences and deposits (about 16) corresponds to the zones or contacts with them. Three of the mineralization zones are marked on the resistivity section (Figure 1).

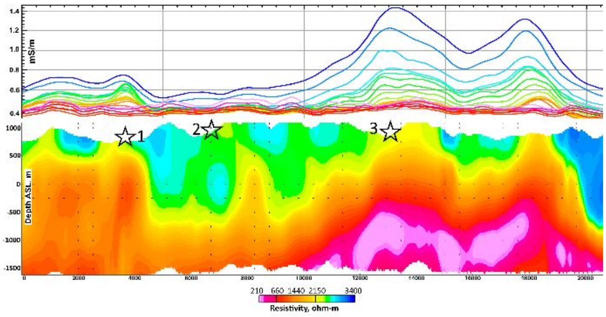

Figure 1. Top panel - apparent conductivity profiles of MobileMT along the survey line L2420 (cold colours – low frequencies, warm – high frequencies in the range 28-14,321 Hz), and bottom panel - inverted resistivity-depth section, with positions of known mineralization (1-Kahovskoe, 2-Nachalnoe-II occurrences, 3 – Perevalny deposit).

In the Dukat Ore Field, deep drillholes encountered large biotite granite and granodiorite intrusives, forming a dome structure at a depth of 1200-1500 m (Seltman et al., 2010). One of the drillholes shown over a MobileMT resistivity section along a part of a line crossing the ore field (Figure 2). The dome structure is well reflected in the geoelectric image, and the contact with granitoids approximately corresponds to the 1750 ohm-m isoline.

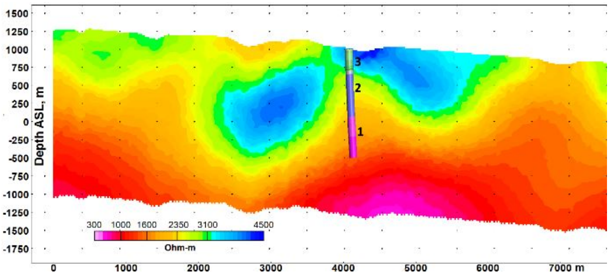

Figure 2. MobileMT resistivity section with a deep drillhole position in the Dukat Ore Field (1- granite and granodiorite intrusive dome, 2-rhyolite lavas, ignimbrites and tuffs, 3-andesite lavas intercalated with black argillites).

We created a surface of the resistivity level which apparently outlines not only the granitoids face and the depth of the dome structures, but products of hydrothermal activity, i.e., controlling the mineralization subvertical zones and channels arising to the surface (Figure 3).

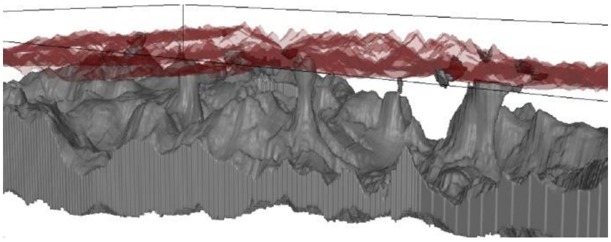

Figure 3. 1750 ohm-m surface (grey) of a portion of the surveyed area.

Resistivity-depth slices combined in the 3D view display features in the resistivity distribution in any chosen depth level in the whole frame of the surveyed area (Figure 4).

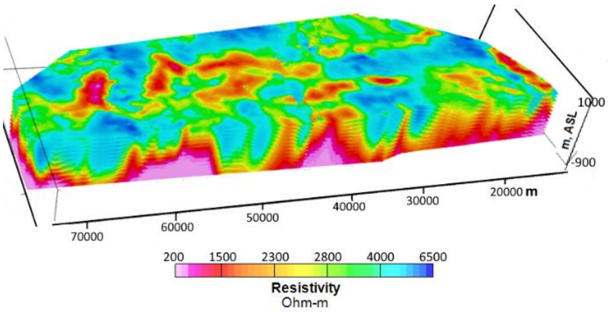

Figure 4. Resistivity-depth slices of the surveyed area in 3D view.

Combined analysis of the retrieved resistivity model with positions of known mineralization occurrences and deposits, shows good correlation between low resistivity anomalous zones and the mineralization spatial distribution (Figure 5, Figure 6). For the first time in the ore district, controlling the mineralization deep structures can be interpreted and evaluated on the areal basis.

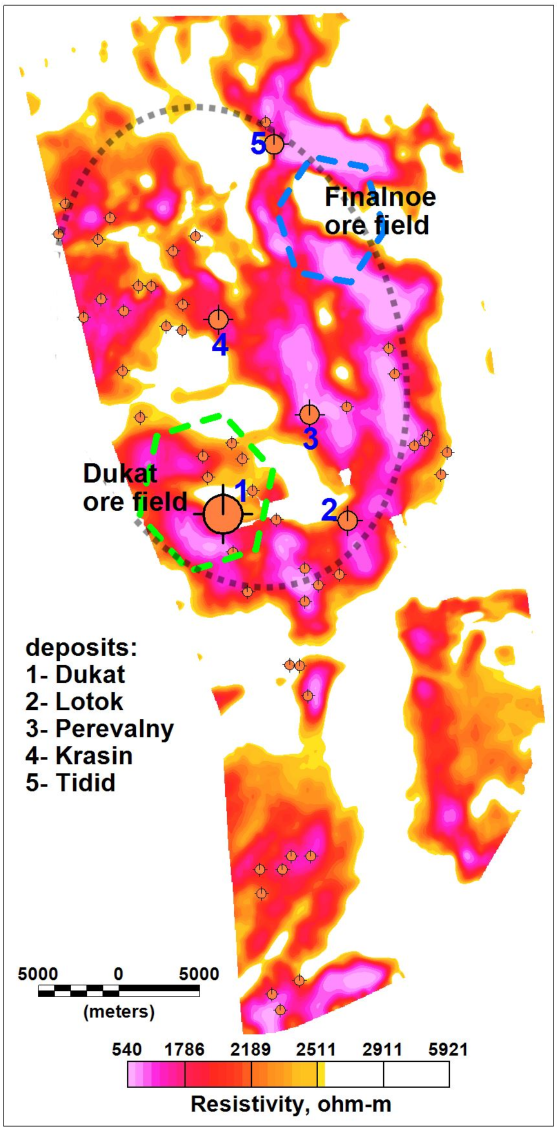

Figure 5. Low resistivity-depth slice 0 m ASL with occurrences and deposits positions.

The deep dome-similar structures mostly contribute to low resistivity distribution in deep slices, like 0 m ASL (Figure 5), and the subvertical zones, interpreted as fault systems presumably acted as pathways for mineralised fluids, contribute more into the upper part of the rift geological sequence (Figure 6).

As the data in Figure 1, Figure 5, and Figure 6 shows, the subvertical zones with low resistivity mostly relate to and arise from the deep low resistivity uplifts, and known mineralization positioning, in most cases, consistent with both the deep dome-similar structures and the subvertical fault zones. The SE part of the survey area, with prospective conductive zones where known mineralization is absent, is not investigated due to broad spread of alluvial sediments. The notable feature of the resistivity distribution on low-level depth slices (Figure 5) is that conductive anomalies (or dome structures) form a regional near circular caldera type structure (grey dotted line in Figure 5).

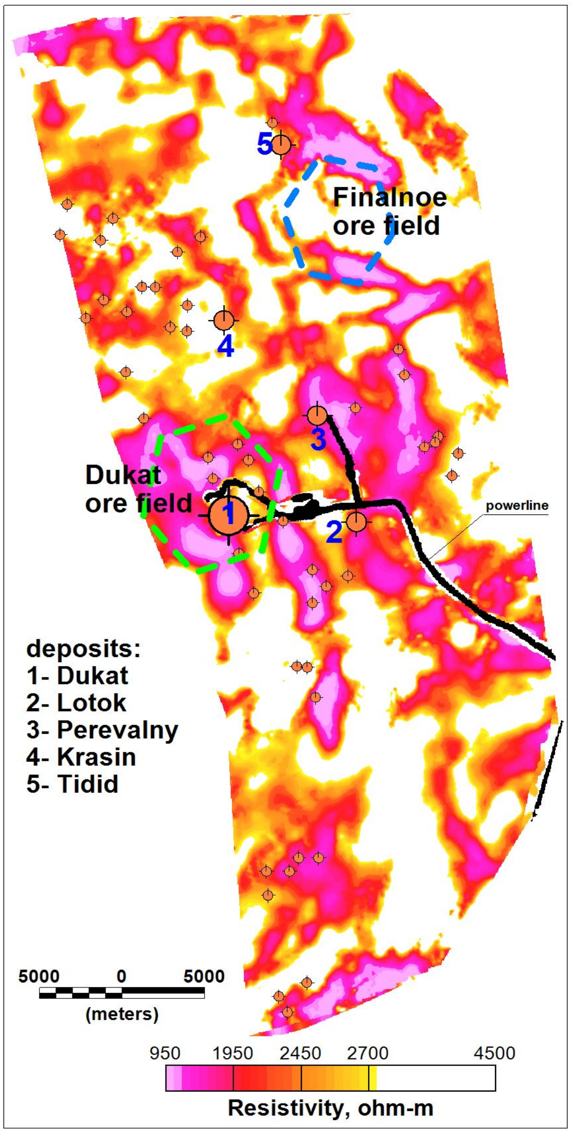

Figure 6. Low resistivity-depth slice 500 m ASL with occurrences and deposits positions.

CONCLUSIONS

The case history describes the use of MobileMT natural electromagnetic fields aerial measurements over the central part of the Omsukchan volcanic trough structure with epithermal silver-base-metal specialization. The mining region has high potential for expanding the reserve base of currently operating mines, but it is considered underexplored specifically for in-depth positioned mineralization controlling structures.

The airborne MobileMT technology, based on natural electromagnetic fields, has distinct practical advantages for mineral exploration in the region - sufficient depth of investigation, covering deep and upper layers of the subsurface geology; sensitivity to any direction of geoelectric boundaries; confident recognition of resistivity differentiations in the broad range, including thousands ohm-m.

For the first time in the ore district, a resistivity model, constructed from the MobileMT survey, 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; and regional, presumably caldera type structures. Comparison of the recovered geoelectric model with deep drilling data and positioning of known mineralization occurrences and deposits shows high correlation with the structures and geoelectric features. The airborne EM data can be used as a base for test drilling and other ground-related detailed investigations aimed at new discoveries. In short, the MobileMT data example and modelling results in this case study have shown that the airborne EM technology was an effective and economic tool for mineral exploration over a large portion of the Omsukchan mining district.

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