ZTEM data inversion and interpretation using the UBC-GIF MTinv3D code: A case history at the Silver Queen project, British Columbia

Peter L. Kowalczyk
Mira Geoscience Ltd.
Advanced Geophysical Interpretation Centre
Vancouver, British Columbia, Canada
peterk@mirageoscience.com

Patrick B. M. van Kooten
Mira Geoscience Ltd.
Advanced Geophysical Interpretation Centre
Vancouver, British Columbia, Canada
patrickv@mirageoscience.com

SUMMARY

Z-axis Tipper Electromagnetic (ZTEM) surveys are rapidly becoming an integral part of geophysical exploration. This airborne AFMAG EM system measures the tipper of natural magnetotelluric fields at frequencies typically from 30Hz to 720Hz.

The ZTEM system responds primarily to current channelling and operates at lower frequencies than active-source EM systems. As such, it maps bulk conductivity of the ground to lower values and greater depths than active-source airborne EM systems. ZTEM is particularly suited to mapping large regional structures, sulfide vein systems and intrusives that characterize porphyry copper deposits. The 3D resistivity model produced by inversion of ZTEM data using the UBC-GIF MT3Dinv code proves very useful for focussing exploration into the most prospective zones of a project area.

The Silver Queen polymetallic vein system is a high grade past producer south of Houston, British Columbia. Current exploration around the old Silver Queen mine by New Nadina Explorations Ltd is conceptually based targeting of a blind, buried bulk tonnage deposit near the old mine and deeper in the mineralized system. Inversion of the ZTEM data and the magnetic data acquired over and surrounding the old mine, has identified a favourable setting close to an interpreted nearby intrusive body and within a large regional structure that flexes around it. Exploration is now focussed in this area, with a deeply penetrating induced polarization, electrical resistivity, and magnetotelluric ground survey completed over the target areas to direct drilling. The ZTEM processing and the inversion results from the ZTEM and magnetic data are presented.

Key words: ZTEM, AFMAG, airborne electromagnetics, 3D EM inversion modelling, natural source EM

INTRODUCTION

The Z-axis Tipper EM (ZTEM) system, developed by Geotech Ltd (Legault et al., 2009), measures the tipper of the MT field in both the along-line (X) and cross-line (Y) polarizations. The tipper (Vozoff, 1972) is the ratio of the vertical magnetic field, as measured with a large horizontal loop receiver towed beneath the survey aircraft, and the horizontal magnetic field as measured at a reference base station located in a non-anomalous area within or near the survey area. The real and imaginary components of the tipper are recorded for both the X and Y polarizations of the MT field. Measurements are typically made from 30Hz to 720Hz, with 3 or 4 frequencies per decade. The low frequency limits of the system are determined by the speed of the aircraft since a certain number of cycles need to be measured to acquire a reading, and the high frequency limits are determined by the strength of the MT signal, which falls off at higher frequencies. Thus, four measurements are made at each frequency, comprising of the real and imaginary components of the X and Y polarizations. Thus, if measurements are made at 6 frequencies then 24 separate readings would be recorded at each receiver location along the line.

Conductive anomaly trends produce cross-over anomalies in the polarization which crosses their strike. These are straightforward to recognize yet difficult to interpret in a quantitative way. When 6 frequencies are being measured, the 24 separate maps produced are confusing and the imaginary-component response maps are non-intuitive, even to an experienced geophysicist. Cross-over anomalies can also be produced by topographic effects, the strength of the anomaly being a function of the ground conductivity, the amount of topographic variation, the polarization direction and the frequency being measured. The combined inversion of this data to produce one consistent model of ground conductivity provides a unified interpretation of the whole dataset.

ZTEM INVERSION

The UBC-GIF MT3D inversion codes (Farquharson et al., 2002, 2003) produce robust 3D conductivity models. However, careful preparation of the data is critical before one can achieve a good result. The most important aspects of this preparation are the assignment of relative errors to the data and the removal of bad data, which is usually spatially associated with power lines. We have found that visual inspection of the each component of the data is essential. Bad data can usually be recognized visually and are subsequently removed prior to attempting a trial inversion of the remaining data. As the topography contributes to the response, and the topographic effect needs to be accounted for by the inversion, it is necessary to have a good topographic model. The geodetic datum and horizontal datum of the GPS and Digital Elevation Model (DEM) need to be checked carefully to ensure they are as expected. This is normally done by comparison with a reference DEM in a known datum, for example the SRTM data which is available worldwide in the WGS84 datum, within which elevations are quoted with respect to mean sea level.

After careful review and acceptance of the ZTEM data, it is necessary to design a discretised mesh for the project area, taking cognizance of the size of the area, the flight line spacing and the topographic relief. If the area is being inverted in multiple meshes and being merged together afterwards, then sufficient overlap needs to be assigned in the design of the meshes to allow the results to be merged together successfully.

Given the design of an appropriate inversion mesh, and comfort with the data quality, then the next step is to do some trial inversions of the data using one frequency at a time. These trials are done in order to check data quality and to assign appropriate errors to each data point. If the inversion process converges at each frequency to an acceptable level of detail, then the data at that frequency can be put aside for use in the final combined frequency inversion. The errors assigned to each frequency can be balanced to assign appropriate weights to each frequency at the single frequency inversion stage. Once the data at frequency is tested using a single frequency inversion, then all the data can be combined together to do a multi-frequency inversion.

The multi-frequency data is often first inverted at a reduced resolution, using a coarser mesh discretization. The result from this may be used as a starting model for the final inversion at the highest resolution and the largest mesh that can be run using the computational resources available. The limits of resolution are principally determined by the errors assigned to the data. The size of the inversion mesh is primarily controlled by the amount of memory and compute time available on the computer being used. In a parallelized computing environment, each frequency requires four processors, so a six frequency inversion would require a 24 processor cluster. The current version (V.201001) of the MT3Dinv code normally takes one or two days per iteration, which can add up to a week or ten days to achieve a solution using a good high end computing cluster. Actual compute times vary considerably depending on individual hardware configurations, available system resources and increase non-linearly with increasing mesh size.

MAGNETIC INVERSION

The magnetic data acquired during a ZTEM survey can be inverted separately to generate a 3D magnetic susceptibility model that provides additional and corroborating geological information about the survey area. The code normally used to invert the magnetic data is the UBC-GIF MAG3D inversion package, which operates in a similar way to the UBC-GIF MT3D program package. The design of meshes as well as the optimization of the input data for this program are well understood in the geophysical industry and are thus not discussed in detail here.

SILVER QUEEN ZTEM DATA

In June 2011, a ZTEM survey was flown over the Silver Queen project area of New Nadina Explorations Ltd. The project area is south of the town of Houston, British Columbia and not far from the Huckleberry mine, which is a producing copper, molybdenum porphyry deposit. The Silver Queen mine is a vein type polymetallic deposit and past producer. The target sought by New Nadina Explorations Ltd is a large, bulk tonnage type deposit close to and below the Silver Queen vein system. There are abundant small veins and showings around the old mine, but no clear indications of where the mineralizing source fluids for the mine came from, nor where one should look for a blind, bulk tonnage deposit that might be associated with the mineralized vein system. The mine sits in a metavolcanic and metasedimentary sequence, and the presence of an intrusive close by was inferred from an anomaly in an old airborne magnetic survey, but the survey did not cover a large enough area to allow the geometry of any magnetic stock present to be interpreted.

The ZTEM and magnetic inversion results were reviewed to identify areas close to the Silver Queen Vein system, near or within an intrusive stock, and within a regional structure that could control the emplacement of a disseminated, bulk type mineral deposit. Figures 1 and 2 show the results of these inversions. A favourable area next to an inferred intrusive, close to the south end of the Silver Queen Vein system, and within a jog in a large NE-SW trending regional fault system has been identified. Ground follow-up using a deeply penetrating induced polarization, resistivity and magnetotelluric system has been done and deep drilling is scheduled to commence in September and October 2011. The combination of geophysical and drilling programs, applied sequentially but using information from one in designing the other has allowed a rapid, focussed, and cost effective exploration program.

CONCLUSIONS

The ZTEM and magnetic inversion results have provided direction to a ground geophysical and drilling program looking for a buried disseminated bulk tonnage deposit close to and below the known Silver Queen vein system. Exploration has been focussed into a particular area in a cost effective and rapid manner, providing targets for a deep drilling program while reducing the risk and cost of the program. The ZTEM survey has identified the Silver Queen Vein system as an electrically resistive trend; it has identified a potential intrusive below the vein system that may be genetically related, and it has identified a flexure in a regional structure passing by this intrusive that is a favourable setting for a blind bulk tonnage deposit. Inversion of the magnetic data provides independent corroboration that the electrically resistive body is likely an intrusive, as the resulting magnetic model shows a coincident stock-like magnetic body. Follow-up ground geophysical surveys have identified several prospective induced polarization targets and these are currently being drilled.

ACKNOWLEDGMENTS

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FIGURES

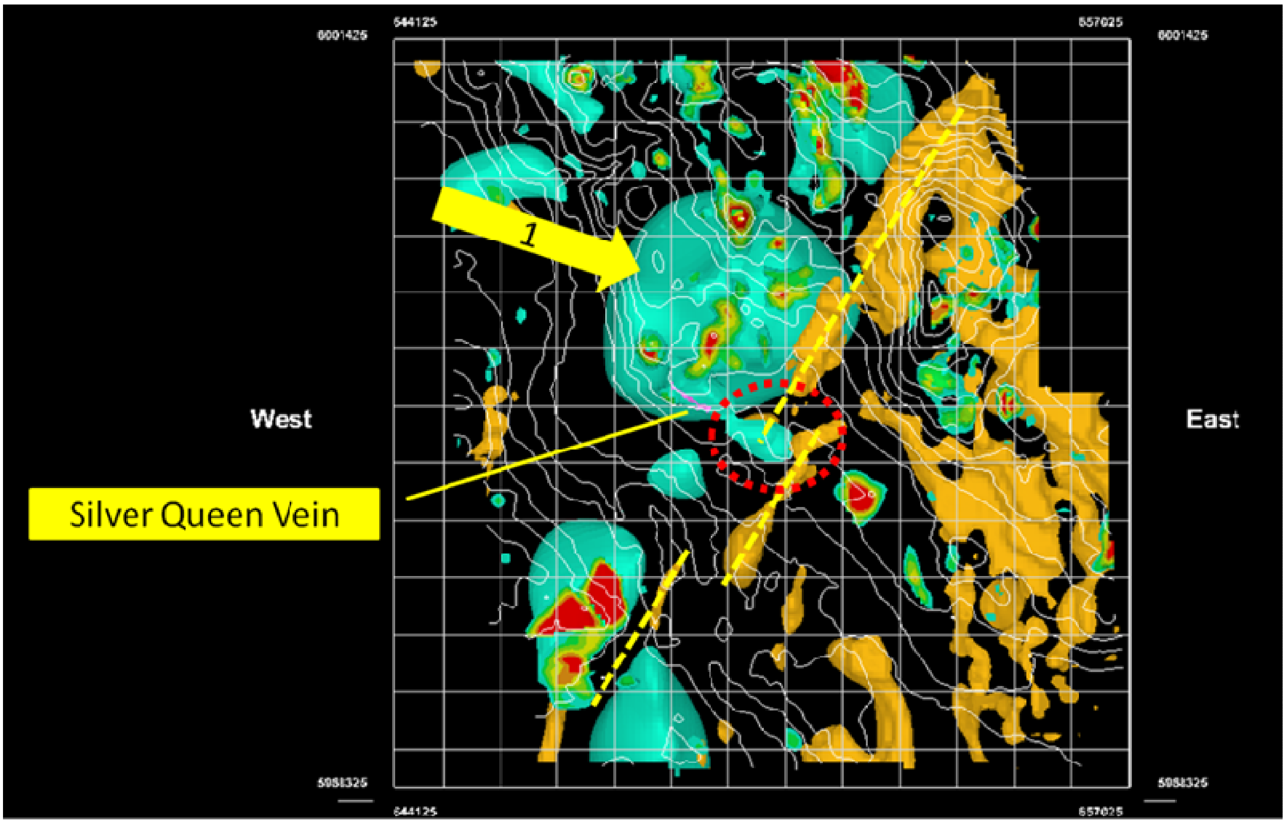

Figure 1. ZTEM INVERSION RESULTS: The 500 ohm.m and 12.5 ohm.m isosurfaces derived from the ZTEM inversion model are shown in light blue and light brown respectively. The Silver Queen Vein system is shown as a small purple body striking NW. The large balloon shaped light blue resistive isosurface immediately below and to the north of the Silver Queen Vein system is interpreted to be an intrusive. The interpreted NE-SW regional structure is shown as a yellow dashed line. The red ellipse identifies the favourable region where a zone of structural accommodation for the NE-SW fault system is present close to the intrusive.

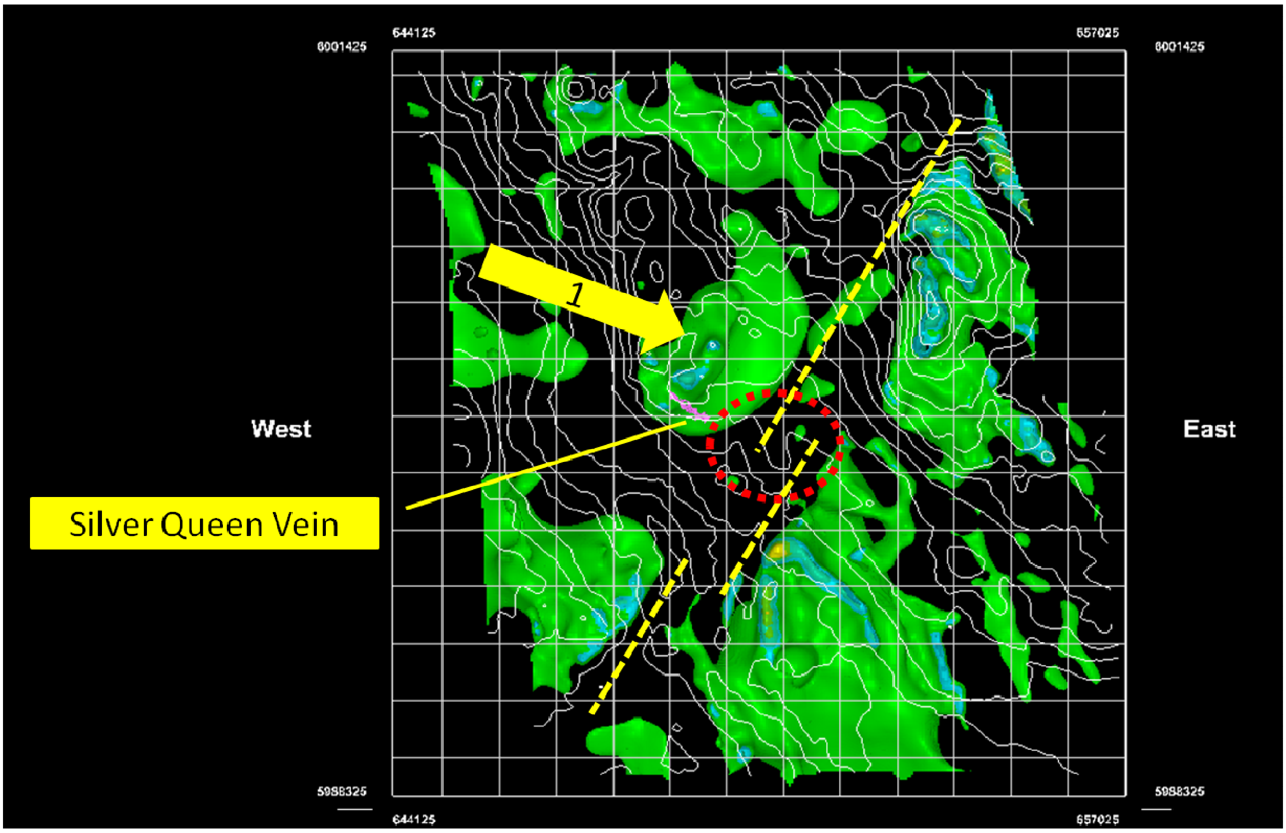

Figure 2. MAGNETIC INVERSION RESULTS: The 0.002 SI isosurface derived from the magnetic susceptibility model produced by the 3D inversion using the UBC-GIF MAG3Dinv code is shown in green. Note that the intrusive interpreted from the ZTEM resistivity model below the Silver Queen Vein system corresponds with a volume of increased magnetic susceptibility. The NE-SW structural trend corresponds with a magnetic low.