Gold exploration in Chukotka region by using audiomagnetotellurics

E.Ermolin[1], O. Ingerov[2], A.Savichev[1]
[1] National Mineral Resources University (NMRU), Saint-Petersburg, Russia, Ermolin_stud@list.ru
[2] Phoenix Geophysics Ltd. Toronto, Canada, Oingerov@phoenix-geophysics.com

SUMMARY

Chukotka is a promising area for prospecting of precious metals. In August 2013 one of the licensed areas for audiomagnetotellurics (AMT) survey was done by NMRU for exploration prospective areas. Five components of natural electromagnetic (EM) field of the Earth of two electric (E_x , E_y) and three magnetic (H_x, H_y, H_z) have been measured at the main grid (295 sites) and three magnetic components (magnetovariational profiling (MVP) were done at detail profiles (55 sites). The spacing between AMT-MVP sites was 40 meters, the distance between the profiles - 250-400 meters. The survey took 27 days (including data analysis and geological interpretation). Precision tripods application for 3 induction magnetic sensors installations significantly increased field productivity and accuracy of measurements, provided the minimum damage to the environment. Graphics, pseudo-sections, maps of AMT-MVP parameters and 2D inversion results confirmed the known position of the gold-bearing vein zone and allowed to predict its position shifted north. Significant role in the operational understanding of the geological structure played express AMT-MVP data interpretation methods. The survey results show that AMT-MVT technique is the powerful instrument for exploration of epithermal gold - silver mineralization in Chukotka.

Keywords: audiomagnetotellurics, magnetovariational profiling, tipper, induction vector, epithermal quartz gold ore veins.

INTRODUCTION

In recent years, the most popular in the ground (O Ingerov 2009), and the aero-electromagnetic prospecting (Orta 2012) applier methods there were that use variations of natural electromagnetic (NEM) field of the Earth. Application of NEM methods doesn't require the creation of a powerful artificial current source, what significantly reduces the surveys cost and facilitates their implementation in remote regions. In ground version of the technology implemented in the 5-component measurements which includes two independent methods: audio magnetotelluric sounding (AMT) (Berdichevsky and Dmitriev 2008), (Chave and Jones 2012) and magnetic variation profiling (MVP) (Rokityansky1982, O Ingerov 2009 I Ingerov, 2011). In the AMT method measured 4 horizontal components (E_x, E_y, H_x, H_y) of NEM field are measured, and MVP are measured three orthogonal magnetic components of NEM fields: H_x, H_y, H_z. One of the advantages of technology AMT-MVP is the ability to perform rapid interpretation of data in the field (O Ingerov and Ermolin 2010, Ermolin et al. 2011) and the results of this interpretation can be used to correct the direction of drilling. In this paper there is the example of AMT-MVP methods application for epithermal gold-silver deposits exploration in Chukotka. Investigated area is hosted by Late Cretaceous andesitic rocks of the Okhotsk – Chukotka Volcanic Belt in Chukotka province, Far East Russia (Figure 1a).

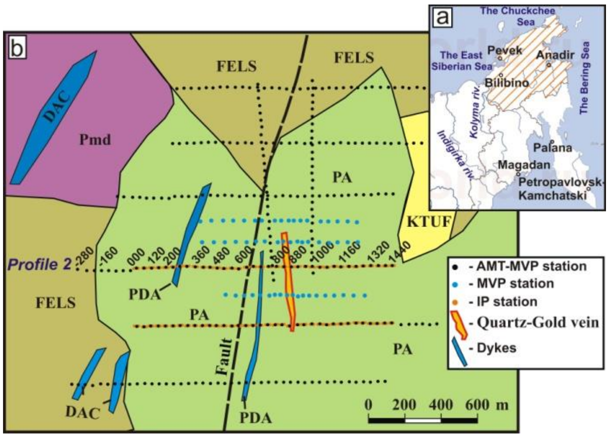

Figure 1. Position of Chukotka region on North-East part of Russia (a), geology scheme of investigation area with location of AMT-MVP, MVP and IP stations (b) Legend (b): DAC – Dacite; FELS – 'Felsic' volcanic rocks, undivided - rhyolite, dacitic-rhyolitic lapilli tuff; PDA - Porphyritic dacitic andesite; PA – Porphyritic andesite; PMd – Microdiorite, Porphyritic.

The epithermal quartz vein has high gold grades associated with various vein textures, including colloform banding. There is a low amount of sulfides in the veins; the Ag/Au ratio is ~12:1. These features are typical of epithermal vein deposits that can be referred to as low sulfidization. In the area the Cretaceous volcanic sequence is up to 1300 m thick. It consists of: Upper Felsic sequence rhyolite tuffs and lavas, Middle sequence andesitic to basaltic flows and fragmental rocks, Lower Felsic sequence rhyolite and rhyodacite tuffs and ignimbrites. Mineralized gold veins are located near or at the top of the middle andesite unit. The Upper Cretaceous calc-alkaline volcanic rocks are discordantly overlain by basalts, and are cut by basaltic dikes (Figure 1b). Epithermal gold ore vein (thickness ~3 m) in the area of exploration do not coming to the surface and covered by 100-150 m flow unit of mafic volcanic rocks (with layers of ash tuffs). The gold vein along their strike was controlled by dike of porphyritic dacitic andesite. Tectonics of this area is defined by the presence of general NNW fault zone and post-ore sub latitudinal auxiliary faults. They may break and displace of northern part of gold vein in the horizontal and vertical planes. The work was aimed AMT-MVP to determine the position of the known veins, to evaluate the displacement amplitude veins and determine the position of the offset portion of the vein zone in the plan.

METHODIC

AMT-MVP field work was done by using multichannel automated, synchronized with GPS recorders of fifth generation MTU-5A (O. Ingerov 2009, O. Ingerov 2011). To measure the electrical components used 40 -meter electric dipoles (E_x, E_y) and non polarized electrodes PE-4. For measuring 3 magnetic components (H_x, H_y, H_z) – AMTC-30 induction sensors were used. Precision tripods Tri3/30 were used for magnetic sensors installation at the sites. More detailed methodology of fieldwork AMT-MVP considered in (Ingerov and Ermolin, 2011). A total of 297 points of the AMT-MVP at 8 profiles and 55 points MVP for detailed profiles were done during 27 days August 2013 survey. Distance between sites was 40 m, the distance between the profiles of 250-400 m. Eight 5-channel systems were involved (geophysical equipment weight was about 600 kg) and 10 experts personal take part in the survey. Low level of NEM fields, as usual for polar latitudes significantly complicated the survey. All measurements were performed with remote reference site. The resistivity (RES) method as well as induced polarization (IP) one was performed using the same receivers and transmitter T3. The central gradient array was used. The length of transmitter dipole was 1 km. Current in the dipole AB was ranged from 2 to 3 A. The length measuring dipoles was 20 m; spacing between sites was 20 m.

Data analysis was done by using WinGLink software. The typical apparent resistivity (ρ), impedance phase (φ) AMT curves, tipper amplitude (T_a) and tipper phase ($T_φ$) MVP curves for profile 2 are shown in figure 2. In general, the entire profile is characterized by good quality AMT-MVP curves and a regular change their shape from site to site. AMT phase curves are consistent amplitude, indicating the absence of contrast conductive inhomogeneities. Curves ρ at western unit (Figure 2, index 1) in the frequency range of 10,000 Hz to 1000 Hz are close to horizontal level of 200-300 ohm-m on the left branch of 200-300 ohm-m. Longitudinal ($ρ_{TE}$) and latitudinal ($ρ_{TM}$) curves are basically conformal. The slight discrepancy $ρ_{TE}$ and $ρ_{TM}$ curves at site 0320 is explained by the influence of a steeply dipping dacitie dikes. Both curves have sloping descending branch and a minimum at around 100 Hz. The minimum (Figure 2, 2.3) shifts to the higher frequencies (150 Hz) at the east part of the profile, which indicates an increase in the resistivity of the section. In the central column (Figure 2, 2.2) have the highest and the divergence $ρ_{TE}$ and $ρ_{TM}$ AMT curves in the range from 100 to 10000 Hz. For the Eastern bloc (Figure 2, 3) characterized by a very seasoned form of the curves, a distinction is observed only for very high frequencies (over 1000 Hz). Greatest interest is the change in shape of the phase curves of the tipper. Below 100 Hz for the whole profile on AMT curves observed ascending branches and divergence of curves $ρ_{TE}$ (steeper) and $ρ_{TM}$ (more gentle). This effect is greatest discrepancies in the west profile and minimal in the eastern part.

In Figure 3a shows a map of phase effective impedance phase at the frequency 300 Hz. Gradient trending zone (fault) is divided the profile into two roughly equal parts - east and west .The zone of particular interest is an elongated central zone of low values of phase, located east of the fault . Zone consists of three fragments, which are displaced by latitudinal faults for 120-300 m to the east relative to each other as one move from south to north. South fragment is fixed only on one profile, so its exact position and stretch are questionable. At the same time, position and stretch the central and northern fragments are determined reliably. With the central high resistivity object gold-quartz vein with thickness 3 m is related so it is reasonable to believe that the northern high resistive fragment shifted by 120-200 m to the east also has an interest. Map of tipper amplitude at frequency 7200 Hz (Figure. 3b) generally confirms the conclusions from the phase map, only high-impedance objects here marked by gradient zones.

Results of 2D inversion were done for all profiles by using WinGLink software. Geoelectrical cross-section for profile 2 has been shown at figure 4. ρ, φ of TE-mode and TM-mode in frequency range from 10000 to 50 Hz and tipper amplitude (T_a) in frequency range from 10000 to 3000 Hz was used for joint 2D inversion. MRS was achieved at 1.3%. Above Geoelectrical section the graphs of geological and geophysical parameters are shown. On the section at 200 meters west from the fault allocated high resistivity zone in the depth range 100 - 600 m. In the center of this area is drilled gold-bearing quartz vein. Over a high resistivity zone is also observed: positive gold, silver and arsenic anomaly in subsoil, positive anomaly of the phase difference of the longitudinal (φ_{xy}) and transverse (φ_{yx}) components, as well as local anomaly constant magnetic field of the Earth (T).

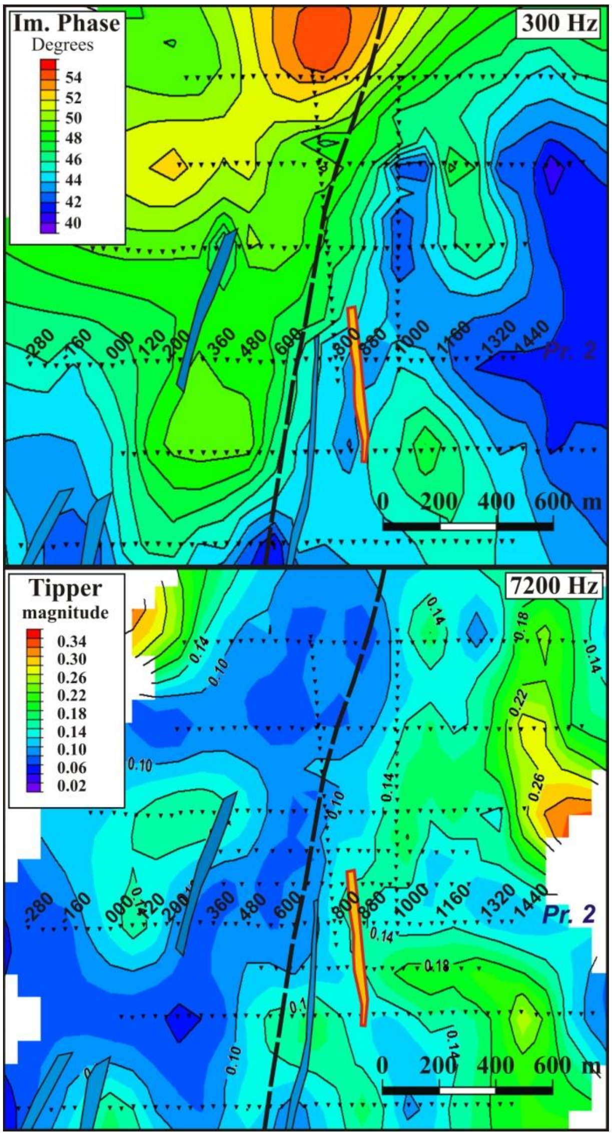

Figure 3. Invariant impedance phase map at 300 Hz (a) and Tipper magnitude map at 7200 Hz (b).

Such features can be regarded as the search criteria for the blind auriferous quartz veins. Most pronounced over the auriferous vein zone manifested negative anomaly phase of the tipper (blue curve on figure 4 -I). Noteworthy negative tipper phase values in the eastern part of the tipper profile (station 1280-1400). According to the results of 2D inversion there, at depths of 100-300 m high resistivity is detected as well as the gold anomaly in subsoil. All of this can be attributed to this anomalous object on promising gold ore mineralization. In the western part of the profile (around site -100) also observed negative anomaly tipper phase and Magnetic field of the Earth. There are also appearances of vertical inhomogeneity on high the high resistive geoelectrical section as well and as negative anomaly tipper phase and constant magnetic field of the Earth. The positive anomaly of molybdenum (little bit shifter to the east is present), which is typical for under ore body cut of gold-silver epithermal columns.

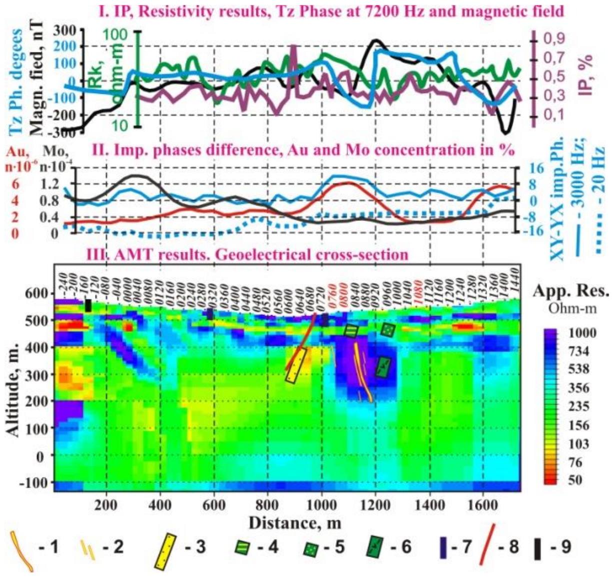

Figure 4. Survey result comparison. I – IP, resistivity results, natural magnetic field and tipper phase at 7200 Hz; II – ground geochemistry results and difference between XY and YX impedance phase for 3000 and 20 Hz; III – Geoelectrical cross-section (2D inversion of AMT-MVS data); Legend for III: general drill holes results (1-6): 1 – main gold ore vein, 2 – thin ore veins, 3 – felsic ach tuff, 4 – strongly altered basalt lava, 5 - strongly alternated basalt tuff, 6 – andesite - basalt lava; geological mapping information (7-9): 7 – dyke position, 8 - fault zone position, 9 –andesite – rhyolite contact.

CONCLUSION

License area, located in a remote, inaccessible, environmentally sensitive Chukotka region in summer 2013 has been explorated by methods AMT-MVP methods, as well as by IP. The preliminary interpretation reports were done in short time and they allow adjusting drilling. Precision tripods for induction magnetic sensors installation have played significant role in the performance of the survey.

Application of the AMT – MVP method provided reliable information about the tuff and lava bursts (first 100-150 m), and the structure of volcanic and dyke complexes to a depth more than 800 m. The zones of potential gold mineralization is controlled by the main dikes, less acid composition, stand as high resistivity anomalies in the depth interval 150-500 m These zones reliably traced between profiles. Tectonic faults fixed gradient by zones, changing the structure response parameters AMT-MVP as at the plan as well as at the Geoelectrical sections.

For the conditions of Chukotka technology AMT-MVP methods are optimal for prospecting and exploration for epithermal gold mineralization. Application of IP method was not effective.

ACKNOWLEDGEMENTS

We acknowledge the support of the Mining Community in Chukotka for access and the opportunity to publish.

REFERENCES

Berdichevsky M.N. and Dmitriev V.I. (2008). Models and methods of magnetotellurics: Springer-Verlag, Berlin, Heidelberg, 563 pp.

Chave A.D. and Jones A.G. (2012). The Magnetotelluric Method. Cambridge University Press, 2012, 552 p.

Ingerov O et all. (2009). Non-grounded Surface Electroprospecting Technique., 70th EAGE Annual Conference. Amsterdam #6149

Ingerov O. (2011). Latest trends in the development of electroprospecting hardware for ground and marine surveys. 5-th All Russia School-Seminar on Electromagnetic Sounding of the Earth, V2, p 449-454.

Ingerov I (2011). The Method of Multifrequency Magnetovariationel Profiling", 5-th All Russia School-Seminar on Electromagnetic Sounding of the Earth, V2, p 449-454.

Orta M et all (2013). Passive and active helicopter EM survey comparison over the 501 Project Cu-Zn volcanogenic massive sulfide at McFauld's Lake, Northern Ontario, KEGS PDAC Seminar.

Ingerov O and Ermolin E (2011). The results of AMT survey at Patomsky crater. 73rd EAGE Conference & Exhibition incorporating SPE EUROPEC 2011 in Vienna, Austria 23-26 May 2011. P. 303-306.

Ingerov O and Ermolin E (2010). The parameter estimation of 2-D conductive isometric bodies by singular points at the tipper frequency characteristic. Proceedings of 20th Induction Workshop IAGA, Giza, Egypt-2010, September 18-24. P. 303-306.

Ermolin E, Ingerov O, Ingerov I (2011) Mapping of vertical conductivity bodies by MVS. All-Russian school-workshop dedicated to M.N. Berdichevsky and L.L Vaniyan of electromagnetic researches of the Earth. Saint-Petersburg, Russia, 2011. P. 245-249.

Rokityansky I.I. (1982) "Geoelectromagnetiv Investigation of the Earth Crust and Mantle", Spinger-Verlag, Berlin, Heidelberg, New York, 378 p.

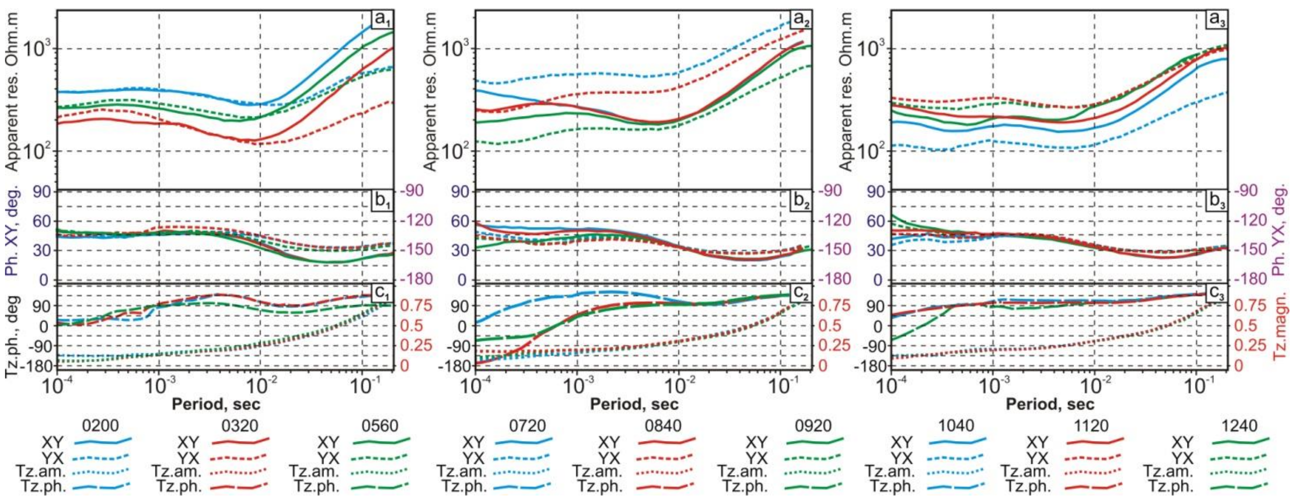

Figure 2. Type of AMT-MVP curves for westerly (index 1), nearly (index 2) and easterly (index 3) of vein zone. Type of AMT curves (a, b): apparent resistivity (a) and Impedance phase (b) along XY direction shown by solid line, along YX direction shown by dotted line. MVP curves (c): tipper magnitude shown by dots, tipper phase shown by dotted line. The AMT-MVP station names are shown under the period axes.