ADDITIONAL EXPLORATION OF GOLD DEPOSIT IN CHUKOTKA BY AMT AND MVP

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Abstract

The integration of geochemical and geophysical methods was applied to epithermal gold-quartz veins exploration in Chukotka tundra (North-East Russia). The feature of the investigated area is that the gold-quartz veins are blind and are located 50-120 m below the surface under the layers of low-resistive andesitic tuff. The Audiomagnetotelluric Soundings (AMT) and Magnetovariational Profiling (MVP) methods have been applied. Ability to carry out work, productivity and the accuracy of measurements were achieved via application of precision field tripods for magnetic sensors installation. The analysis of AMT-MVP data has shown its high sensitivity to geoelectrical cross-section changes in wide depth interval. The position of known quarts-gold vein zone has been determined as a high resistivity zones. Consequently, based on the AMT and MVP data interpretation results, prognosis of new dikes has been done in the late 2013. All prognoses were confirmed by 2014 drilling program and new discoveries are estimated at around 50 ton of gold. Therefore, AMT-MVP could be considered as a very useful technique for these geological conditions.

Introduction

During the last ten years the scope of application of the 5-component measurements of the Earth's natural alternating electromagnetic field has increased significantly in mining. The 5-component measurements include two methods. The first is the audiomagnetotelluric soundings (AMT) of the natural alternating electromagnetic (EM) field based on four (4) horizontal component measurements (E_x, E_y, H_x, H_y) (Berdichevsky, Dmitriev, 2009). The second one is the Magnetovariational Profiling (MVP) method which is based on three (3) orthogonal magnetic component measurements (H_x, H_y, H_z) (Rokityansky, 1982). The application of the precision tripods for induction magnetic sensor installation during field surveys has allowed to carry out field work on any terrain and climate conditions with AMT-MVP methods from the beginning of the 21st century with practical expense. The AMT method has the capability to reconstruct the horizontal-layered structure of cross-section adequately. The MVP method is very sensitive for vertical inhomoginieties. As a result, the combination of these two methods allows reconstructing a geoelectrical cross-section accurately and making it possible to solve a wide range of mapping and prospecting tasks. Moreover, AMT and MVP data processing is easily done jointly.

The main task of our AMT-MVP investigation was the prospecting of epithermal gold-silver vein deposits in hard conditions of the Chukotka region. The investigated area is located in Okhotsk-Chukotka volcanic belt (Figure 1a). The thickness of the Late Cretaceous volcanic host rock reaches 1300 m. They are composed of the 3 sequences: upper - felsic tuff and lavas, middle - andesite-basalte tuff and lavas, and clastic rocks, and bottom - rhyolite and rhyodacite tuff and ignimbrite. The prospected ore bodies are small-thickness (about 3-5 m) low-sulfidized (up to 5%) quartz veins with high (10-30 ppm) gold concentration and Ag/Au ~ 12:1. The simplified geological map of the investigated area is shown in Fig. 1b. It is divided into two parts (East and West) by a large NNE-trending fault. Porphyritic andesite (PA) lava, rarely - tuff is ore hosted rocks. On the west and north of the area they are covered by felsite layers (FELS - rhyolite, dacitic-rhyolitic lapilli tuff). Veins along their strike are often controlled by dikes of porphyritic dacitic andesite (PDA), rarely – dacite (DAC). According to the previous geochemical mapping of the area and the drilling data (lines 1 and 2, stations №840), the steeply dipping blind quartz vein with Au-Ag mineralization was localized. The vein thickness is up to 3 meters and the depth to its top edge is 100 m in the south and 120 meters in the north. The gold ore quartz vein occurs among durable andesitic lavas and disappears in less strong overlying tuffs. According to the drilling data obtained in 2013, the northern part of the vein was lost. As it will be shown below, due to the presence of the high-conductive tuffs at the top of the andesitic packs, traditional methods of apparent resistivity and induced polarization were not effective.

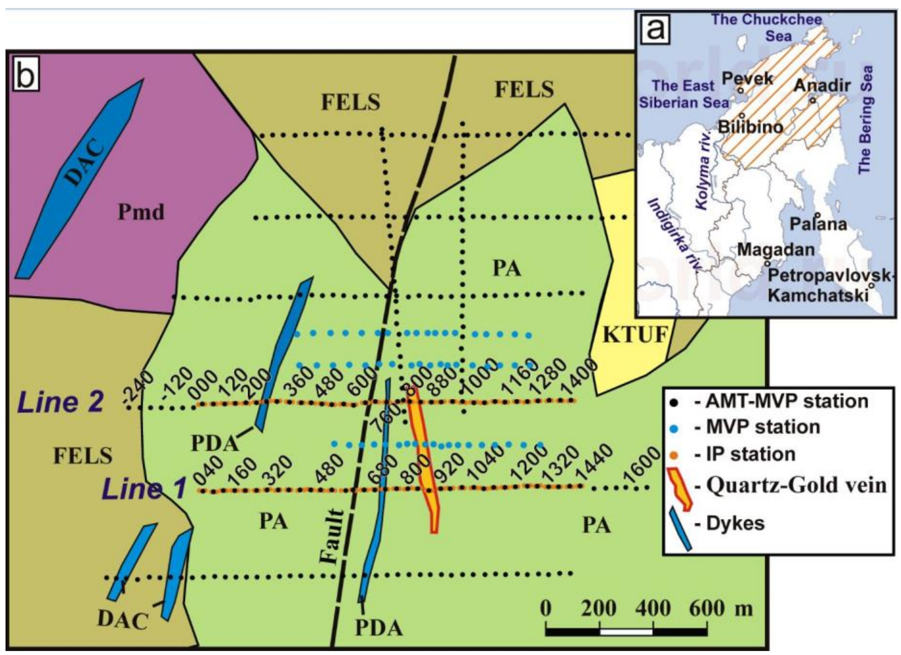

Figure 1: Chukotka region position (a), geology scheme of investigation area (b).

Measurement Technique and Data Analysis

The AMT-MVP field work was done with MTU-5A 5-channel automated receivers of the 5th generation (Ingerov, 2009), synchronized by GPS. The distinct feature of this field survey was the application of the precision field tripods TRI-3/30, which allowed quick and precise installation of the three (3) magnetic sensors on all types of surface in weather conditions and without digging any holes in the ground. The AMT-MVP field work procedure was described in detail (Ingerov, Ermolin, 2011). In total, 297 AMT-MVP stations along 8 lines and 55 MVP stations along additional lines were recorded. The 40 meters spacing between stations and 250-400 meters distance between the profiles was used. Eight (8) 5-channel systems were used for the data acquisition (total weight of the equipment - about 600 kg) and 10 operators took part in the survey. A very low natural EM-field signal, typical for the polar region, has complicated field measurements. The remote reference station technique was applied for each site. Field work, data processing, analysis and interpretation all have been carried out directly in the field camp within 35 days. The resistivity and induced polarization (IP) investigations were done by with non-polarized electrodes and MTU-5A receivers. All measurements have been fulfilled in the middle gradient zone. 1 km power line was used; length of the receiver line and spacing between stations were 20 meters. IP and resistivity results have shown a weak connection between response function and undercovered geology structures (Figure 3-a,b-I). As a result, the IP investigations were stopped.

The data analysis of the AMT-MVP phase parameters in the area was more informative. The map of invariant impedance phase at 300 Hz has been shown in Figure 2a. The central sub-meridional elongated zone of the decreased impedance phase value (line 1 and 2, stations 800-880) is the most notable. The known gold vein (2013 borehole data) is localized in this zone (orange color) where the decreased phase value is 80-120 m shifted to the east on the north part of investigated area. This shifting (and 2D inversion results) has allowed to forecast the position of the vein in the north-east direction. This anomaly was drilled at the beginning of 2014. As a result, the new gold vein with industrial content was discovered (yellow contours in Figure 2). The zone of induction arrows turn has been shown on the induction arrows map at 7200 Hz in the south-middle part of the area (Figure 2b). This zone corresponds to the known dyke position. The arrow directions abruptly change from NW to NE over the upper part of the dyke. This turn zone is 100-120 m shifted to the east in the northern part of the area (blue dash line). This fact independently confirms the structure shifting to the east direction in the northern part of area. The negative impedance phase anomaly in the southern part of the area did not generate a considerable urgency in 2013, because this anomaly was detected by one AMT-MVP line only. Nevertheless, this anomaly was drilled in 2014, and as a result, another gold vein was detected. The known gold veins appear in the gradient zone on the tipper magnitude map at 7200 Hz (Figure 2c).

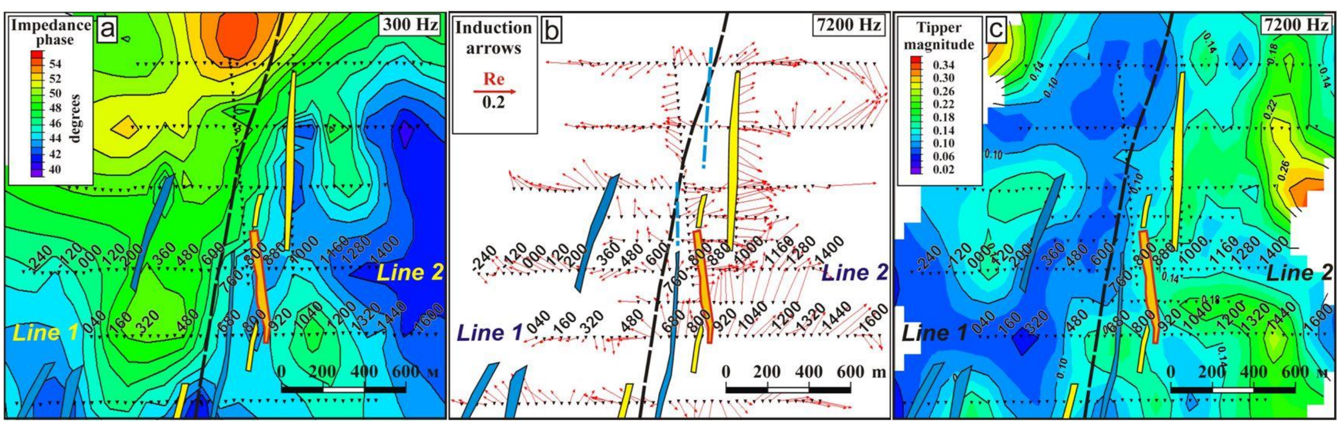

Figure 2: Maps of invariant impedance phase at 300 Hz (a), induction arrows (b) and tipper magnitude (c) at 7200 Hz. Orange veins were found by drilling data till 2013, yellow veins are 2014 boreholes results.

Results

The 2D inversion results were received for all profiles. The apparent resistivity and the impedance phase curves (TE and TM modes) in frequency range from 10 000 to 50 Hz and tipper magnitude curve in frequency range from 10 000 to 3 000 Hz have been used jointly for 2D inversion.

The average MRS was 1-1.3% for all the lines. Geoelectrical cross-sections along lines 1 and 2 are shown in Figure 3-a,b-II. The resistivity of main rock types was measured for better understanding the geoelectrical cross-sections. According to these measurements the main conductors in the geoelectrical cross-sections are the constitute tuff layers and strong alternated rocks. On the other hand, poor-conductive zones (resistors) correspond to andesite dykes and fresh andesite-basalt lavas.

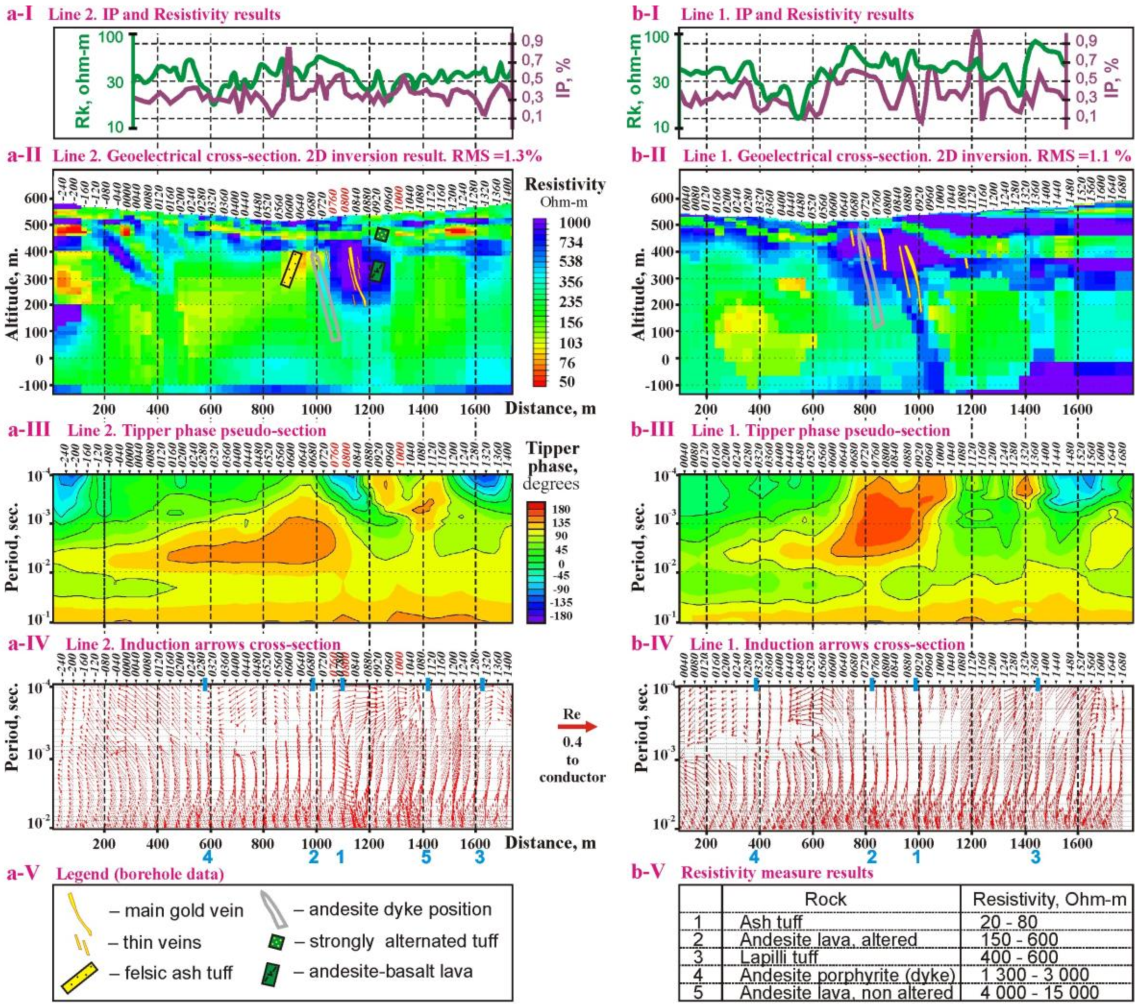

Figure 3: AMP-MVP and IP results comparison along lines 2 (a) and 1 (b). The blue rectangles on the upper part of induction arrows cross-sections (a,b-IV) are resistive zones.

The high-resistivity zones correspond to the known veins zones positions on geoelectrical cross-sections. Moreover, on section 2 the vein zone is thin and it corresponds to the thin high resistive zone (stations 760-960). The vein zone in cross-section 1 is larger and it corresponds to the large high-resistive zone (stations 600-1120). The deep thin channel of high-resistivity is located along the dip direction of the main vein zone. This channel appears in both lines in all the investigated depth range.

The anomaly objects appear well on the tipper phase pseudo-sections as the vertical gradient zones. This affirmation was proved by 2D modeling basis in the (Ingerov, et al., 2013, Ermolin, et al, 2014). The tipper phase pseudo-sections analysis along lines 1 and 2 was done by the authors.

According to the analysis, the fact that known position of veins corresponds to the vertical gradient zones has been revealed. In other words, the type of tipper phase curve changes steeply when passing over anomalous objects. It is visible in line 2 (stations 760-880) as well as in line 1. Two anomalous objects can be detected by gradient zones in line 1. The first small vein appears at high frequencies (8 000 – 10 000 Hz) between stations 760 and 840. The second vein is larger and it appears as a vertical gradient zone of the tipper phase in 300 – 3 000 Hz frequency band in passing from 920 station to 960 station.

It should be noted that besides the known vein zone, there are two more prospective zones. In the east of the area, the steeply-falling high-resistivity zone is crossed by line 1 (stations 1320-1400) and line 2 (stations 1280-1360). This zone strike direction is similar to the known central vein zone strike. Very noticeable are vertical gradient zones on tipper phase pseudo-section which correspond to the eastern zone. It can be seen in line 1 as well as in line 2. The outlook of the eastern zone is increased due to this fact. The second perspective zone is located in the west (near station 320, line 1).

The induction arrows cross-sections are more simple for express-analysis (Figure 3-a,b-IV). The arrows are directed to the conductor (or from the resistor) in cross-sections. Thus, the arrows turn zones (the direction of arrows change from West to East) correspond to resistive anomaly zones. The arrows amplitude decreasing zones correspond to local resistive zones on the large (regional) conductor background. The induction arrows cross-section analysis along 1 and 2 lines has been carried out by the authors. The found resistive zones have been marked by blue rectangles on the upper part of cross-sections (Figure 3-a,b-IV). The zones have been named from 1 to 4 under the cross-sections. First of all, it should be noted that the known vein position is safely detected in line 1 (sharp turn of induction arrows), as well as in line 2 (local arrows turn between stations 780 and 800) by resistive zone#1. The position of dacite dyke is well detected by resistive zone#2 in both lines. The resistive zone#3 appears as a local minimum of arrows amplitude. This zone position corresponds to “East zone” detected by geoelectrical cross-sections and tipper phase pseudo-sections. The resistive zone#4 appears clearly as the point of arrows turn in line 1 and clear local minimum zone in line 2. It is also noticeable that this zone was not detected clearly by using 2D inversion even though resistive zone#4 corresponds to the complex lithogeochemistry anomaly axis. This fact makes this zone very perspective. The pronounced resistive zone#5 detected on the cross-section along line 2 is located between two conductive objects in the upper part of geoelectrical section (Figure 3-a-II, 470 m altitude). The pronounced tipper phase changing in 1 000-10 000 Hz frequency range corresponds to this zone. It is obvious that zone#5 is not perspective.

Conclusions

Due to AMT-MVP technique application, the position of the known blind gold vein has been detected. The vein displacement to the east in the northern part of the area has been forecast. The predicted position has been confirmed by boreholes after AMT-MVP investigation. The known gold veins are detected by high-resistivity zones in the depth range from 150 to 500 meters. Veins can also be detected by gradient zones on tipper phase pseudo-sections and by turn points of induction arrows. The large vein zone has a near-vertical high-resistive thin deep channel. Two more perspective gold-containing zones have been founded in the investigated area as the result of AMT-MVP technique application. The AMT-MVP method combination is the most optimal geophysical technique for forecasting thin blind quartz gold veins in regions with poor infrastructure and vulnerable environment (such as Chucotka tundra). The use of precision tripods for magnetic sensors installation plays the main role in the productivity of field work and the accuracy of measurements.

Acknowledgements

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