Geophysical Methods of Identification of Ore Control Structures of Orogenic Gold Deposits in Low-Contrast Terrigenous Rocks by Petrophysical Characteristics

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Abstract. The paper presents the analysis of characteristics of abnormal geophysical fields of the ore control of the Malo-Tarynskoe orogenic gold deposit in Verkhoyano-Kolymsky folded area, the Northeast of Russia. It is located in terrigenous rocks of the top Triassic, poorly contrast on petrophysical characteristics. Ore bodies of the Malo-Tarynskoe deposit are presented by the mineralized crushing zones with veinlet-disseminated and vein-disseminated mineralization. To identify the features of manifestation the ore control in geophysical fields land geophysical surveys are conducted by the methods of high-precision magnetic exploration and electroinvestigation. Magnetoprospecting works have established the low-amplitude mosaic structure of the magnetic field of the Malo-Tarynskoe deposit. The main magnetorevolving structure is the Samyr granitoid massif which is allocated with a magnetic minimum (-99 nT). Extreme positive values of the magnetic field are connected with hornfelsed ores in the zone of contact metamorphism (170 nT). Various anomalies as low-magnetic, mainly linear ones caused by explosive violations are distinguished (-12 – 20 nT). In the electric field, the abnormal zones have the linear nature of various extent and intensity. Pro-deleting of anomalies changes from sublongitudinal to northwest. The anomalies of low electrical resistance, generally trace zones of crushing and jointing (208-2300 ohm*m). In general, they are grouped in three "regional" abnormal areas of the northwest and North northwest orientation of low electrical resistance and correlated with the situation of the ore control zones of the Malo-Tarynskoe fault (208 – 1600 ohm*m). Sites with frequent alternativeness and alternating electric anomalies indicate lithologic heterogeneity of the environment (2500 – 10000 ohm*m). The study has shown magnetoprospecting to be effective when mapping magmatic formations and explosive violations. They allow delineating intrusive bodies and allocating hornfelsed zones. The electric profiling application by the method of a median gradient solves a wide range of geological tasks. Apart from allocation of the structures controlling gold mineralization in faint terrigenous ores, electro-investigation allows to carry out the lithologic partition of permafrost rocks in the territories blocked by friable deposits of considerable power.
1. Introduction

Geophysical methods are widely used in the search and tracing of ore-controlling structures, especially in closed areas [1]. The complicating factors of their use in the Verkhoyano-Kolymsky folded area are the development of permafrost rocks and weak differentiation according to the petrophysical characteristics of the rocks hosting ore bodies.

The studies were performed on the example of the Malo-Tarynskoe orogenic gold deposit (MTOGD) located in the central part of the Kular-Nera shale belt at the intersection of the Adycha-Taryn fault (ATF) with the zone of latent transverse Kurdat fault [2]. ATF is represented by a set of faults and fractured zones of the north-west and submeridional strike. Ore-bearing rocks are Norian sediments of the Upper Triassic - interbedding sandstones and siltstones with intercalations of calcareous sandstones and sandy siltstones. Within MTOGD, small dyke-like bodies of bases are known, and to the north-west are the Kurdat and Samyr granodiorite-granite massifs of the Tass-Kystybyt magmatic belt [3]. The structural plan of the field is determined by the position on the western wing of the Malo-Taryn syncline of the Taryn-Elgin synclinorium. Most of the fall rocks (30-70\(^{\circ}\)), complicated by folds of several generations, are in the northeast and east. MTOGD ore bodies are represented by mineralized crush zones with vein-veinlet and vein-disseminated mineralization. Mineralized zones have a complex morphology, often linear sections are replaced by pinches and swells. In the broken down, variously-oriented systems of quartz veins and veinlets with arsenopyrite nests, phenocrysts of galena, sphalerite, chalcopyrite and gold are manifested. Vein-veinlet gold-quartz mineralization is unevenly distributed, characterized by high gold contents up to several hundred g/t. In addition to quartz (85-95\%), ankerite (5-15\%) and ore minerals are present in the veins - about 1-2\%. A series of mineral associations is distinguished: 1) pyrite-arsenopyrite-quartz (metasomatic), 2) pyrite-arsenopyrite-quartz (gange), 3) gold-chalcopyrite-sphalerite-galena (polysulfide), 4) sulfosulfate-carbonate [3]. Impregnated gold-sulphide mineralization is manifested both in crush and fold zones with a thickness of up to several tens of meters, and in the enclosing terrigenous rocks, forming fairly extensive halos of gold-bearing pyrite and arsenopyrite to varying degrees. The average gold grade in ore zones varies from 2.75 to 13.31 g/t. In pyrite-arsenopyrite-quartz metasomatites, the gold content in pyrite reaches 10.1 g / t, in arsenopyrite 73.2 g / t. The oreberezites are represented by sericite-sulphide, carbonate-sulphide and quartz-carbonate-sulphide facies.

2. Materials and research methods

Geophysical studies were performed using high-precision methods of magnetic and electrical prospecting in the northern and central parts of the Malo-Tarynskoe deposit. Magnetic surveying work was carried out in a polygonal version of the networks 50x10 and 500x10 m, according to the method of single observations at ordinary points with the MMPOS-1 equipment. At the reference points and points with anomalous values of the magnetic field, the number of measurements was increased to 3-4, the average value of the observed field was taken as a reference.

Electrical prospecting was carried out in the modification of electric profiling using the method of a middle gradient with the MARY-24 meter and the Astra-100 generator. The maximum spacing of the line AB was 4.5 km, the minimum - 3 km. The MN receiving line size was 20 m, the measurement step was 10 m. The distance between the profiles changed from 50 to 500 m. The position, source and end points of the profiles and the direction of the moves were recorded in the WGS-84 system using GPS receivers.

To assess the accuracy of geophysical work, in addition to ordinary observations, control measurements were carried out in an amount not less than 5% of the total number of physical points. A complex of geophysical methods was used to identify faults, determine the boundaries of intrusive
bodies, identify and track areas of increased sulfidation, mineralized crush zones and lithological separation of rocks [1, 4, 5].

3. Results and discussion

As a result of the research, a small-amplitude mosaic structure of the MT OGD magnetic field was established. Low-magnetic, mainly linear anomalies of various signs were identified in the research area. The trend of linear anomalies varies from north-west to sub-longitudinal, the length does not exceed 2 km. The intensity of the anomalies varies from -4 to 19 nT. The structure of the anomalous magnetic field of the northern part of the MTOGD is defined by the Samyr granitoid massif (Figure 1). The massif is characterized by a magnetic minimum up to -99 nT. The negative anomaly is framed by a zone of positive values of the magnetic potential with intensity from 71 to 170 nT. Extreme positive magnetic field anomalies are likely caused by hornfelsed rocks in the contact zone of the Samyr massif with host rocks. The intensity of the anomalies decreases with distance from the massif with a gradient of 0.01 nT/m.

![Figure 1. Anomalous magnetic field of hornfelses and the Samyr granitoid massif](image)

1 – contour of Samyr massif, 2 - contour of hornfelses

Detailed electrical prospecting at a 1: 5000 scale allowed us to distinguish two groups of anomalies within the MTOGD (Figure 2). The first group of electrical anomalies is located in the western part of the object under study. It consists of parallel closely spaced linear anomalies of the north-west strike,
mainly, of increased electrical resistance. The intensity of the anomalies varies from 2,500 to 10,000 ohm * m, and the width from 30 to 60 m. The second group consists of fan-shaped linear anomalies of elevated electrical resistance. The specific features of the identified anomalies are their limited length (500–800 m, less often more than 1000 m) and a change in the strike from north-western to the sublongitudinal.

The area under study is characterized by a closely parallel arrangement, frequent alternation, and alternating electrical anomalies. This indicates that during detailed electrical prospecting, along with the zones of crushing and jointing, lithological differences of rocks composing the territory are distinguished. Sandstones correspond to increased values of electrical resistivity, and siltstones and mudstones correspond to lower values of electrical resistivity. Electrical surveys at a 1: 50000 scale allowed us to identify the «regional» anomalies of north-western orientation (Figure 3). Anomalous zones corresponding to the mineralized crush zones are characterized by low electrical resistance. The width of the linear anomalies ranges from 60 to 350 m, the intensity is 325-2600 ohm * m. The identified electrical anomalies are correlated with the Malo-Taryn branch of the Adycha-Taryn fault.

**Figure 2.** Graphs of apparent electrical resistance of the Malo-Tarynskoe gold deposit

1 - axes of low electrical resistance anomalies, 2 - axes of high electrical resistance anomalies
Figure 3. Identified electrical anomalies within Malo-Tarynskoe gold deposit
1 – contour of Samyr massif, 2 – axes of main electrical anomalies

4. Conclusions
The study has shown that magnetic prospecting is effective in mapping igneous formations. It allows the contouring of intrusive bodies, as well as the location of hornfelsed areas. The use of electric profiling using the middle gradient method allows solving a wide range of geological problems. In addition to the selection of OGD structures controlling, electrical prospecting allows lithologic separation of poorly differentiated host permafrost rocks based on their petrophysical characteristics.

Acknowledgment(s)
The authors express special thanks to Y.P. Sobyanin and V.N. Sanin for assistance in carrying out field work in the Malo-Tarynskoe gold deposit.

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