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«Central Asian Academic Research Center» LLP is pleased to announce that “News of NAS RK. Series of Geology and Technical sciences” scientific journal has been accepted for indexing in the Emerging Sources Citation Index, a new edition of Web of Science. Content in this index is under consideration by Clarivate Analytics to be accepted in the Science Citation Index Expanded, the Social Sciences Citation Index, and the Arts & Humanities Citation Index. The quality and depth of content Web of Science offers to researchers, authors, publishers, and institutions sets it apart from other research databases. The inclusion of News of NAS RK. Series of Geology and Technical Sciences in the Emerging Sources Citation Index demonstrates our dedication to providing the most relevant and influential content of geology and engineering sciences to our community.

«Орталық Азия академиялық ғылыми орталығы» ЖШС «ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы» ғылыми журналының Web of Science-тің жаңаланған нұсқасы Emerging Sources Citation Index-те индекстелуге қабылданғанын хабарлайды. Бұл индекстелу барысында Clarivate Analytics компаниясы журналды одан әрі the Science Citation Index Expanded, the Social Sciences Citation Index және the Arts & Humanities Citation Index-ке қабылдау мәселесін қарастыруда. Web of Science зерттеушілер, авторлар, баспашылар мен мекемелерге контент тереңдігі мен сапасын ұсынады. ҚР ҰҒА Хабарлары. Геология және техникалық ғылымдар сериясы Emerging Sources Citation Index-ке енуі біздің қоғамдастық үшін ең өзекті және беделді геология және техникалық ғылымдар бойынша контентке адалдығымызды білдіреді.

ТОО «Центрально-азиатский академический научный центр» сообщает, что научный журнал “Известия НАН РК. Серия геологии и технических наук» был принят для индексирования в Emerging Sources Citation Index, обновленной версии Web of Science. Содержание в этом индексировании находится в стадии рассмотрения компанией Clarivate Analytics для дальнейшего принятия журнала в the Science Citation Index Expanded, the Social Sciences Citation Index и the Arts & Humanities Citation Index. Web of Science предлагает качество и глубину контента для исследователей, авторов, издателей и учреждений. Включение Известия НАН РК. Серия геологии и технических наук в Emerging Sources Citation Index демонстрирует нашу приверженность к наиболее актуальному и влиятельному контенту по геологии и техническим наукам для нашего сообщества.

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CONTENTS

Y.A. Altay, Zh.M. Dosbaev, A.A. Altayeva, P.M. Rakhmetova, D.B. Absadykov Predictive model for assessing diagnostic significant parameters of acoustic emission: machine learning evidence.....	8
E.T. Alsheriyeu, K.S. Dossaliyev, A.S. Naukenova, B.A. Ismailov Radiation, chemical situations and communal damage caused during possible earthquake in Turkestan region.....	22
B.B. Amralinova, K.S. Togizov, A. Nukhuly, N.Zh. Zhumabay, A.Y. Yessengeldina The nature of the Karasor-Lisakov magnetic anomaly and identification of promising areas for magnetite ore deposits in Kazakhstan.....	31
B. Assanova, B. Orazbayev, Zh. Moldasheva, Zh. Shangitova Decision making on effective control of rectification process in the main column of delayed coking unit in fuzzy environment.....	55
A.O. Zhadi1, A.G. Sherov, L. Makhmudova, L.T. Ismukhanova, E.K. Talipova Climate change impacts on Central Asian high-mountain lakes: the case of Lake Markakol (Kazakhstan).....	73
G.Zh. Zholtayev Geodynamic prerequisites for assessing the hydrocarbon potential of the Balkhash basin.....	93
I. Golabtounchi, A. Solgi, M. Pourkermani, M. Zare The investigation of morphotectonical indexes and seismotectonic activity in Bahjatabad dam –Iran.....	108
V.A. Ismailov, A.R. Rakhmatov, A.S. Xusomiddinov, E.M. Yadigarov, J.Sh. Bozorov Assessment of the soil seismic condition through microseismic measurements (in the example of the city of Bukhara).....	131
L.V. Krasovskaya, V.S. Tynchenko, O.A. Antamoshkin, S.V. Pchelintseva, M.S. Nikanorov Application of machine learning methods as a modern approach to rock analysis.....	146
V.V. Kukartsev, A.A. Stupina, E.V. Khudyakova, I.A. Vakhrusheva, K.S. Muzalev Application of machine learning methods for a comprehensive assessment of the ecological consequences of tectonic activities in the Caspian region.....	158

B. Kulumbetov, M. Bakiev, Kh. Khasanov, K. Yakubov, A. Khalimbetov Earthworks for the construction of an irrigation canal embankment using sandy soil.....	173
K.A. Kauldashev, M.K. Kembayev, A.V. Gusev Results of integrated geological and geophysical studies in the exploration of the Sokyrkoy gold-copper porphyry deposit (Central Kazakhstan).....	190
A. Mussina, G. Baitasheva, G. Medeuova, M. Kopzhassar, R. Amrousse Modern methods of amalgamation of low soluble metals and alloys: contribution to sustainable development and environmental protection (SDG 12).....	206
V. Mukhametshin, R. Gilyazetdinov, D. Saduakassov, M. Tabylganov, M. Sarbopeyeva Influence of variation coefficient of non-homogeneity on the efficiency of selection of optimal technology of hydrochloric acid treatment.....	227
A. Nurmagambetov, A.T. Danabaeva, Z.A. Sailaubayeva, A.M. Katubayeva On the seismicity and seismic potential of the Zhambyl region of Kazakhstan.....	240
N.P. Stepanenko, O.K. Kurilova, A.B. Erkinova, T.M. Kaidash Seismotectonic model of Southern Kazakhstan as a basis for seismic hazard assessment.....	253
J.B. Toshov, K. Yelemessov, B.J. Baymirzayev, D. Baskanbayeva, U.F. Murodbekov Drainage methods of the pit wall massif for efficient groundwater interception in open-pit mines.....	267
A.S. Urazaliyev, D.A. Shoganbekova, M.S. Kozhakhmetov, N.N. Zhaksyngul Development of a local quasi-geoid model of Almaty city using the fast collocation method.....	282
N.S. Faiz, Sh.K. Shapalov, N.P. Tokenov, K.Zh. Smagulov, B.K. Nauryz Assessment of optimal and effective wind farm implementation sites in the System Advisor Module.....	301
V. Yusupov, B. Khaydarov, N. Sattorova, F. Boltayev, E. Khakimov Hydrogeoseismological monitoring of water level and gas changes during earthquakes.....	315

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RESULTS OF INTEGRATED GEOLOGICAL AND GEOPHYSICAL STUDIES IN THE EXPLORATION OF THE SOKYRKOY GOLD- COPPER PORPHYRY DEPOSIT (CENTRAL KAZAKHSTAN)

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Abstract. The article presents the experience of applying integrated geological and geophysical investigations conducted within the Sokyrkoy ore field (Central Kazakhstan), which includes the eponymous deposit as well as a series of ore occurrences and mineralization points of copper, gold, molybdenum, and polymetals. The Sokyrkoy deposit is a copper ore body with a significant gold component and is confined to the central part of the eponymous paleovolcanic structure. The aim of the study was to refine the morphology of the ore bodies, assess the prospects for increasing copper and gold resources, and prepare recommendations for further geological exploration. The research program included high-precision magnetic and gravimetric surveys, electrical prospecting using the TDIP method, lithogeochemical sampling for secondary dispersion halos, and limited core drilling. Comparison of the obtained geophysical data with the generalized petrophysical model of porphyry copper deposits has shown that the studied object generally corresponds to this “reference” model. A clear spatial correlation was established between the supergene enrichment zone and the zone of abrupt changes in apparent resistivity, which led to a revision of the ore body morphology: instead of the previously assumed subhorizontal form, it exhibits a domed structure with flanks dipping to the northwest and southeast. In the northern

part of the ore field, additional subvertical bodies were identified and interpreted as eruptive breccias, likely serving as ore-feeding channels. Based on the results, recommendations for the next exploration stage were developed, including drilling on the flanks and at deeper levels of the deposit.

Keywords: geological and geophysical modeling, electrical prospecting, magnetic survey, gold, copper, hydrothermal breccias, secondary sulfide enrichment zone

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СОҚЫРҚОЙ АЛТЫН-МЫСТЫ ПОРФИР КЕНОРНЫН (ОРТАЛЫҚ ҚАЗАҚСТАН) ЗЕРТТЕУ КЕЗІНДЕГІ КЕШЕНДІ ГЕОЛОГИЯЛЫҚ-ГЕОФИЗИКАЛЫҚ ЗЕРТТЕУЛЕР НӘТИЖЕЛЕРІ

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Аннотация. Мақалада Соқырқой кен өрісінде (Орталық Қазақстан) жүргізілген кешенді геологиялық-геофизикалық зерттеулерді қолдану тәжірибесі келтірілген. Бұл кен өрісінің құрамына аттас кен орны, сондай-ақ мыс, алтын, молибден және полиметалл минералдануының бірқатар көріністері мен пункттері кіреді. Соқырқой кені елеулі алтын компоненті бар мыс кен денесі болып табылады және аттас палеовулкандық құрылымның орталық бөлігіне шоғырланған. Жұмыстың мақсаты – кен денелерінің морфологиясын нақтылау, мыс пен алтын қорларын ұлғайту перспективаларын бағалау және одан әрі геологиялық-барлау жұмыстарын жүргізу бойынша ұсынымдар әзірлеу болды. Зерттеу кешені жоғары дәлдікті магнитометриялық және гравиметриялық түсірілімдерді, TDIP әдісімен электрбарлау жұмыстарын, екіншілік шашырау ореолдары бойынша литогеохимиялық түсірілімдерді және шектеулі көлемдегі колонкалық бұрғылауды қамтыды. Алынған геофизикалық деректерді мыс-порфир кен орындарының жалпыланған петрофизикалық үлгісімен салыстыру нәтижесінде зерттеліп отырған нысанның аталған «эталондық» үлгіге жалпы сәйкес келетіні анықталды. Екіншілік сульфидті байыту аймағы мен меншікті электр кедергісінің күрт өзгеру аймағы арасында айқын кеңістіктік корреляция орнатылып,

кен денесінің морфологиясы жөніндегі түсініктер қайта қаралды: бұрын болжанған субгоризонтальды пішіннің орнына, оның флангтері солтүстік-батыс пен оңтүстік-шығыс бағыттарда еңкейетін күмбез тәрізді құрылым екендігі анықталды. Кен өрісінің солтүстік бөлігінде қосымша субвертикальды денелер анықталып, олар руда жеткізуші каналдар қызметін атқарған ықтимал эффузиялық брекчиялар ретінде түсіндірілді. Зерттеу нәтижелері бойынша барлаудың келесі кезеңіне арналған ұсынымдар әзірленді, оған кен орнының флангтерінде және терең деңгейлеріндегі бұрғылау жұмыстары кіреді.

Түйін сөздер: геологиялық-геофизикалық үлгілеу, электрбарлау, магниттік барлау, алтын, мыс, гидротермалды брекчиялар, екінші реттік сульфидті байыту аймағы

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РЕЗУЛЬТАТЫ ПРИМЕНЕНИЯ КОМПЛЕКСНЫХ ГЕОЛОГО-ГЕОФИЗИЧЕСКИХ ИССЛЕДОВАНИЙ ПРИ ИЗУЧЕНИИ ЗОЛОТО-МЕДНО-ПОРФИРОВОГО МЕСТОРОЖДЕНИЯ СОКЫРКОЙ (ЦЕНТРАЛЬНЫЙ КАЗАХСТАН)

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Аннотация. В статье представлен опыт комплексных геолого-геофизических исследований, выполненных в пределах Соқыркойского рудного поля (Центральный Казахстан), включающего одноимённое месторождение, а также ряд рудопроявлений и участков минерализации меди, золота, молибдена и полиметаллов. Соқыркойское месторождение представляет собой медно-золотой объект, приуроченный к центральной части одноимённой палеовулканической структуры. Цель исследования заключалась в уточнении морфологии рудных тел, оценке перспектив увеличения запасов меди и золота, а также в разработке рекомендаций для дальнейшего проведения геологоразведочных работ. Комплекс исследований включал высокоточные магнитометрические и гравиметрические съёмки, электроразведку методом TDIP, литогеохимическое опробование по

вторичным ореолам рассеяния и бурение ограниченного количества колонковых скважин. Сопоставление полученных геофизических данных с обобщённой петрофизической моделью медно-порфировых месторождений показало, что изучаемый объект в целом соответствует данной «эталонной» модели. Установлена чёткая пространственная корреляция между зоной вторичного сульфидного обогащения и зоной резкого изменения удельного электрического сопротивления, что позволило уточнить представления о морфологии рудного тела: вместо ранее предполагаемой субгоризонтальной формы оно имеет сводовую структуру с погружением флангов в северо-западном и юго-восточном направлениях. В северной части рудного поля дополнительно выявлены субвертикальные тела, интерпретируемые как эруптивные брекчии, предположительно выполнявшие роль рудоподводящих каналов. По результатам исследований разработаны рекомендации для следующего этапа геологоразведочных работ, включающие бурение по флангам и на глубоких горизонтах месторождения.

Ключевые слова: геолого-геофизическое моделирование, электроразведка, магниторазведка, золото, медь, гидротермальные брекчии, зона вторичного сульфидного обогащения

Introduction. The Sokyrkoy ore field, which includes the deposit of the same name, as well as a series of ore occurrences and mineralization sites for copper, gold, molybdenum and polymetals, is located within the administrative boundaries of the Karaganda region, in the northwestern part of the Balkhash region, about 80 km southwest of the city of Balkhash. The Sokyrkoy deposit is confined to the nuclear part of the geological structure of the same name. The object was discovered by M.P. Rusakov in 1928 and subsequently studied by many well-known experts (Seitmuratova, 2015).

Features of the geological structure of the Sokyrkoy ore field and the analysis of geological study

The position of the Sokyrkoy ore field in regional structures

The Sokyrkoy ore field is located within the so-called Coastal (Gulshad-Sokyrkoy-Saryshagan) zone, which is characterized by the development of small intrusions of the Topar intrusive complex, with formations of which numerous copper-porphyry objects of Central Kazakhstan and their volcanic aggregates are associated.

Structurally and tectonically, the ore field is located in the southwestern side of the Kendyk-Sarydalin intrusive volcanic structure, one of the largest in the area. This structure can be characterized as a volcanic depression, the formation of which occurred during the Middle-Upper Carboniferous and ended in the Permian. Actually, the depression is composed mainly of Permian-age volcanites (subvolcanic, vent, and cover facies), as well as hypabyssal intrusions.

Structurally, the position of the ore field is controlled by a central-type paleovolcanic structure measuring 7-8 km, which can be attributed to volcanic

dome structures. In its central part, rocks of the Caledonian structural floor, of the Lower Silurian age, are exposed; the flanks of the building are composed of volcanites of subvolcanic facies and intrusive bodies of the Topar complex.

Sedimentary-volcanogenic carboniferous formations, which are hydrothermally and metasomatically altered to varying degrees, are mainly involved in the geological structure of the ore field. Intrusive bodies of diorite-granodyrite composition are localized in the central part, the formation of which is believed to be associated with the formation of gold-copper mineralization in secondary quartzites and propylites.

Another feature of the ore field is the presence of eruptive breccias in its structure, composing isolated subvertical bodies in the shape of an inverted cone. Small xiphoid bodies (up to 0.6 x 0.2 km in size) break through both sedimentary volcanogenic formations of the Middle Carboniferous and intrusive rocks (Gusev, 2015). *Hydrothermal and metasomatic formations of the ore field*, genetically related to the formation of the Sokyrkoy paleovolcano, they are widespread, mainly represented by propylites, dickite and alunite secondary quartzites and quartz-sericite metasomatites.

Propylitization is mainly developed by andesites, andesidacites and their tuffs and is confined to the periphery of the paleovolcano. To a lesser extent, it is manifested in granitoids, as well as volcanogenic-sedimentary deposits of the Silurian. Propylitization is accompanied by scattered and veined mineralization (mainly of pyrite composition).

Sericite metasomatites are the most widespread. They are developed according to the rocks composing the central part of the paleovolcanic structure. In fact, quartz-sericite metasomatites are represented by a rock consisting of sericite, primary (relict) and secondary quartz, chlorite and pyrite.

Dickite secondary quartzites are dense, massive, ash-gray (sometimes light gray) rocks with a clearly recognizable relict structure of porphyry or eruptive breccia. They consist of a fine-grained quartz and dickite aggregate with a significant amount of hematite. Alunite secondary quartzites occupy the entire central part of the massif, forming a single body elongated in a northeasterly direction. In the section, they occupy the upper parts of the massif, sinking to a depth of 100-150 m from the surface. Macroscopically, alunite quartzites are massive light pink (pinkish-gray) rocks, sometimes with a relict structure of porphyrite or eruptive breccia. A common paragenetic association is alunite and quartz with an admixture of dickite, hematite, sericite and limonite. Alunite is found mainly in the bulk of rocks in association with quartz and other minerals. As a rule, interspersed and veined alunite is cut with quartz stockwork in the absence of reverse relationships (Gusev, 2015).

Hypergenic profile and "ore" zonality of the Sokyrkoy deposit

One of the distinctive features of the Sokyrkoy deposit is the development of a partially reduced hypergenic profile of the copper (copper-porphyry) deposit within its limits (Smirnov, 1951; Chavez, 2000; Sillitoe, 2005). The oxidation zone at the

site is poorly developed and of limited importance, while copper mineralization from the surface is represented by malachite, azurite, and chrysocolla, associated mainly with zones of secondary quartzites that have undergone intensive limonitization. Copper concentrations in the oxidation zone are insignificant and usually do not exceed hundredths of a percent.

The leaching zone is characterized by a wide distribution, sometimes its capacity reaches more than 100 meters. It is characterized by an almost complete absence of copper mineralization. The secondary sulfide enrichment zone is developed almost everywhere and has a capacity from 20-40 m to 180-200 m, with an average content of 0.4% and enrichment sites of more than 1%. The secondary sulfide enrichment zone is usually confined to the area of distribution of alunite quartzites and contains the main industrial concentrations of copper. Below is the zone of primary sulfide ores, at depths below 200 m. In general, it is characterized mainly by low concentrations, where, against the general background of copper content of 0.15-0.3%, there are separate enriched areas with a content of 0.4-0.5%. The main ore mineral is chalcopyrite; secondary copper minerals chalcocite and covellite are also found in small quantities. Gold is localized in all the above-mentioned zones and is concentrated mainly at the level above the zones of copper mineralization, it is contained in copper intersections and below them, at a depth of over 300 m. With depth, the gold content decreases and forms separate ore accumulations separated by content.

"Unresolved" issues and setting goals for modern geological and geophysical research

The last significant stage in the study of the object can be considered the exploration and evaluation work carried out by Tsentrgeolsom LLP in 2012-2014. During these studies, copper and gold reserves were calculated in the C₂ category to a depth of 200 m and the estimated resources in the P₁ category in the deep horizons and flanks of the deposit. During these works, reserves were estimated at 350 thousand tons of copper (with an average copper content of 0.4%) and 15.9 tons of associated gold (with an average content of 0.2 g/t), which allows us to consider the object as an average porphyry-type copper deposit with a significant gold component (Gusev, 2015; Krivtsov, 2010).

According to historical data, the ore zone of the deposit is elongated in a submeridional direction and traced over a distance of about 1.5 km. The morphology of the ore bodies was accepted as elongated stratiform, lenticular, and subhorizontal (Fig. 1). The ore bodies are mostly horizontally lying or slightly undulating, with angles of incidence of the first degrees (to illustrate the accepted morphology, we present a fragment of one of the geological and computational sections constructed across the ore zone of the deposit). The length of the ore bodies along the strike is more than 1,000-1,400 m. Ore bodies contoured by an on-board copper content of 0.2% have an intersected thickness of 2.5 to 30.0 m.

The geological and economic assessment of the profitability of extraction of

the calculated reserves, performed taking into account the operating cost indicators taken from the average values prevailing in Central Kazakhstan at the time of exploration completion, showed that mining of the sulfide gold-copper-porphyry ores of the deposit by quarrying is profitable, however, due to the limited exploration opportunities in 2014, there are numerous uncertainty factors that can significantly affect on the technical and economic parameters of its development.

When analyzing historical materials, the authors concluded that historical exploration was carried out with a technological limitation of depth to 200 m and vertical drilling wells, which allowed geometrization of only a part of the ore deposit confined to the apical, central part of the Sokyrkoy structure.

Thus, during the historical exploration, a representative model of the morphology of the ore deposit was not developed, and the prospects for the development of ore mineralization of the object to a depth and along its periphery were not established. These unresolved issues currently do not allow for an objective geological and economic assessment of the deposit and proceed to its development.

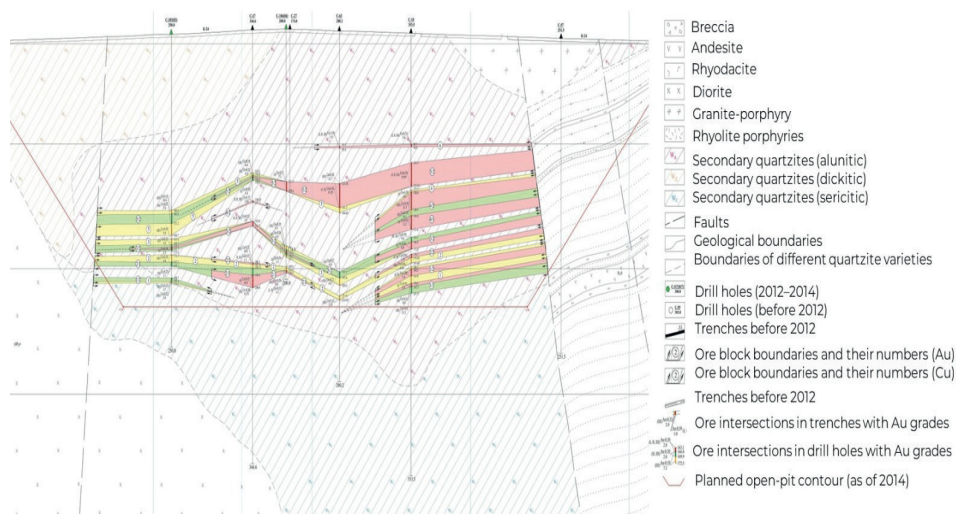


Figure 1 - Geological cross-section (fragment) of Sokyrkoy deposit reserves report with legend (Gusev, 2015)

Materials and Methods

To solve the previously described issues described above, Kazakhmys Barlau LLP carried out a complex of geological exploration works during 2023-2024, including gravity and magnetic exploration (1:10 000), electrical exploration using the TDIP method (profile through 200 m), lithogeochemical survey using VOR (over a 200x200 m network) and drilling of a limited volume of core wells. The applied exploration complex was formed based on the experience of exploration of numerous copper-porphyry (including gold epithermal) ore-magmatic systems around the world (Sillitoe, 2010; Holliday, 2007; Pustozero, 2023;).

The implementation of this exploration complex was aimed at obtaining the operational information necessary to assess the possibilities of increasing the ore reserves of the deposit before proceeding to its planned, detailed exploration.

At the first stage of the work, 1:10,000 scale field magnetic and gravity exploration (with a network of profiles through 100 meters) was carried out with continuous data recording. The volume of work performed at the site was 117 square kilometers. High-precision gravity and magnetic exploration was carried out in order to map tectonic disturbances, identify zones favorable in physical characteristics for the development of increased concentrations of sulfide mineralization in them, as a result, to obtain regional data on the geological and structural position of the ore field and the possibilities of localizing additional objects of a peer level with the Sokyrkoy deposit.

Based on the results of processing and interpreting the data obtained, in addition to standard sets of graphic materials (maps of the anomalous magnetic field, maps of the local component of the magnetic field, a map of gravity anomalies in the Bugey reduction, a map of the vertical gradient of gravity anomalies, etc.), deep three-dimensional models of the magnetic and gravity fields in the studied area were obtained.

Next, electrical exploration was performed using the TDIP method (VP/resistance method in the mode of multipolar pulses in the time domain) in the dipole-dipole modification. The volume of work performed on the 200x50 m network was 117 square kilometers.

Before the start of electrical exploration work, experimental and methodological work was carried out at the site in order to obtain optimal characteristics of the installation, which further provided optimal spatial and parametric resolution when surveying to obtain information up to depths of about 600 m for searching and identifying promising areas associated with the interspersed and veined ore mineralization of the deposit. According to the results of electrical exploration, in addition to the standard set of graphic materials, three-dimensional models of fields of apparent resistance and polarization were also obtained.

In addition, a standard lithogeochemical survey of secondary scattering halos was performed on the area of the deposit and its periphery in order to obtain and outline additional anomalous zones of copper and gold mineralization (Coope, 1973; Moradpouri, 2021).

At the final stage, limited drilling operations were carried out aimed at identifying the nature of the most promising, complex geophysical and geochemical anomalies identified earlier and establishing the morphology of ore bodies to assess the feasibility of further exploration.

Based on the work carried out, a set of geological and geophysical data was obtained, in the interpretation of which special attention was paid to identifying the nature and morphology of ore bodies in order to assess the feasibility of further exploration work. The main search "tasks" to be solved in the course of work and interpretation of the received data were selected:

1. Establishment of a zone of distribution of gold mineralization along the periphery of the deposit and to the depth;
2. Refinement of the morphology of the secondary sulfide enrichment zone;
3. Identification of additional bodies of eruptive breccias in the structure of the object.

Results and discussion

When interpreting the obtained geological and geophysical data, the authors relied on the accepted generalized petrophysical model of the copper-porphyry deposit, with an emphasis on the features of the electrical properties of rocks and their reflection in physical fields (Krivtsov, 2001). This approach is due to the fact that, according to accumulated experience, the most significant information for interpreting the morphology of stockwork-type ore bodies is provided by electrical exploration data (Chen, 2012; Fatehi, 2019).

The uniform zonation of changes in the physical parameters of ore-bearing rocks and ore bodies observed at numerous copper-porphyry deposits allows us to create a common petrophysical model presented in the following form (Fig. 2):

1. *The nuclear part* is characterized by low values of magnetization and density, extremely high electrical resistance, lack of polarizability, and increased radioactivity;
2. *The ore part* is characterized by a sharp increase in electrical conductivity, polarizability and a decrease in resistance due to increased porosity and interspersed sulfide mineralization, an increase in potassium content (manifestation of potassium metasomatism) with a decrease in the contents of uranium and thorium carried into the host medium;
3. *Host rocks*, as a rule, have weak or moderate magnetic susceptibility, increased density, practically do not polarize, have background radioactivity and moderately high electrical resistance (Krivtsov, 2001; Fatehi, 2019).

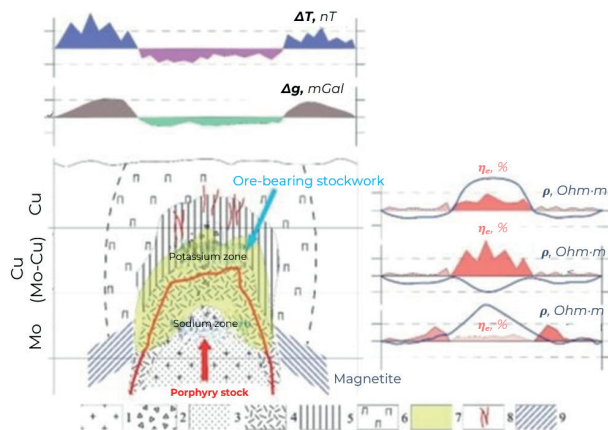


Figure 2 - Generalized FGM of the copper-molybdenum-porphyry deposit (based on materials (Krivtsov, 2001), with additions) 1 – ore-bearing porphyry intrusive; 2 – breccia bodies in a porphyry stock; 3 – metasomatites subordinate to porphyry bodies; 4 - veined-interspersed ore zones (quartz–sericite metasomatites); 5 – mudstones; 6 – propylites; 7 - ore-bearing stock; 8 – fracture zones; 9 – zones with increased content magnetite

For high-quality operations on the interpretation of geophysical data, at the preliminary stage, the properties of the rocks of the deposit (core samples of drilled wells) were determined and systematized.

The determinations were performed using TerraPlus's portable geophysical instrument KT20+, used to measure induced polarization, resistivity, magnetic susceptibility, electrical conductivity, and density of rock samples.

In total, 197 definitions of physical properties were performed for the most representative samples of various lithological (petrographic) rock differences represented in the structure of the deposit. Measurements were carried out for dry and wet samples. In addition, reference data was used for interpretation.

Table 1 shows the average values of quantitative characteristics of the physical properties of various rocks of the deposit, including those from the zones of leaching, oxidation and secondary sulfide enrichment.

Table 1. Average values of physical properties of various rock types of the Sokyrkoy deposit

		The zone	Density, (g/cm ³)	Magnetic susceptibility, (10 ⁻³ SI)	Polarizability, %	Specific resistance, Om*m
1	Quartz-chlorite and quartz-sericite metasomatites	leaching and oxidation	2.70	15.72	6.98	225.98
2	Lavas, tuffs, and tuffobreccias of rhyolites, trachytes, dacites, andesites, and tuffoconglomerates	leaching and oxidation	2.62	19.13	4.59	398.68
3	Alunite secondary quartzites	enrichment	2.74	15.99	7.08	136.83
4	Quartz-chlorite and quartz-sericite metasomatites	enrichment/ protorudes	2.77	8.22	7.73	62.73
5	Granites and granodiorites		2.65	32	2.2	950

As can be seen from Table 1, quartz metasomatites of enrichment and leaching zones with similar mineral composition differ sharply in resistivity values and have similar polarizability characteristics, which indicates the leading value of the resistance characteristic for modeling the enrichment zone of the Sokyrkoy deposit. During the interpretation and modeling of the obtained geophysical data, it was found that, regionally, the Sokyrkoy deposit is a body of multifacial hydrothermal-metasomatically formed quartzites emerging to the surface, most vividly manifested by a high-resistance anomaly of electrical resistivity (maximum resistance values reach 2,000 ohms * m (Fig. 3, 5, 6A-C)) structurally "sandwiched" between two positive magnetic anomalies of an isometric shape (the value of the magnetic field within these anomalies reaches +600 nT) (Fig. 6D, F)), presumably related to

the presence of intrusive rods that do not reach the daytime surface (later, during drilling operations, this hypothesis was confirmed).

Next, we will consider in more detail the morphology of the anomalies of reduced resistance in the context of the ore zone of the deposit (Fig. 3, 5, 6A-C). High resistivity values can be traced to a depth of about 100-150 m from the daytime surface and fix the base of the oxidation and leaching zone of primary sulfide mineralization, the main volume of gold mineralization of the deposit is confined to this zone. From a depth of 150 m, there is a sharp drop in resistance to 10-100 ohms* m, this zone of the resistivity field gradient is associated with a zone of secondary sulfide enrichment (according to the results of further drilling operations, it was found that mineralogically this zone is characterized by the development of fine chalcocite mineralization) and a zone of mixed ores, which in the central part of the object have a "cloak-like" morphology and subhorizontal occurrence.

In some areas of the deposit, the sulfide enrichment zone is also quite clearly expressed in the morphology of the polarization field gradient (Fig. 4).

New electrical exploration data made it possible to model the body shape of the secondary enrichment zone with its "arched" morphology with wings sinking in the north-west and south-east directions (the nature of the occurrence is clearly illustrated in sections of the resistivity field carried out across the strike of the main ore zone of the deposit (Fig. 4)).

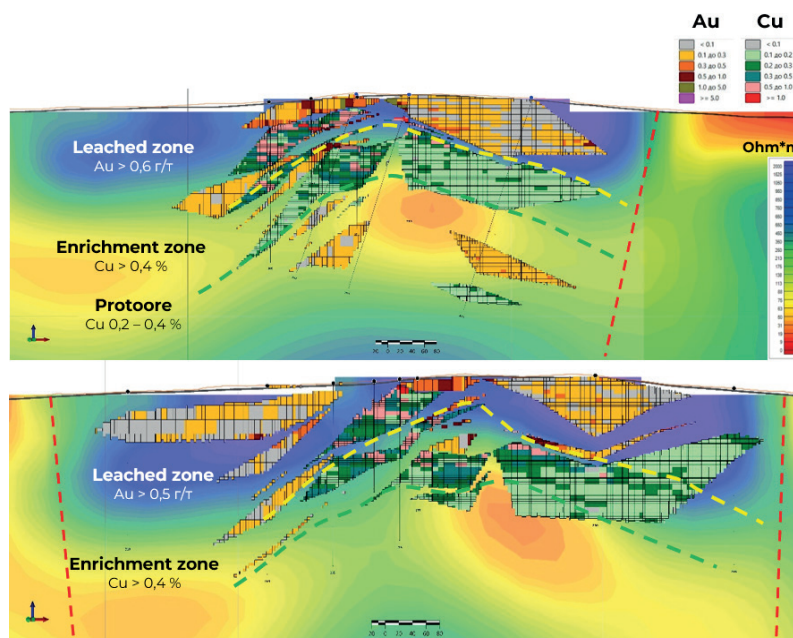


Figure 3 - Cross-sections perpendicular to the strike of the main ore zone of the Sokyrkoy deposit, showing the morphology of supergene zonation areas (resistivity model used as the background)

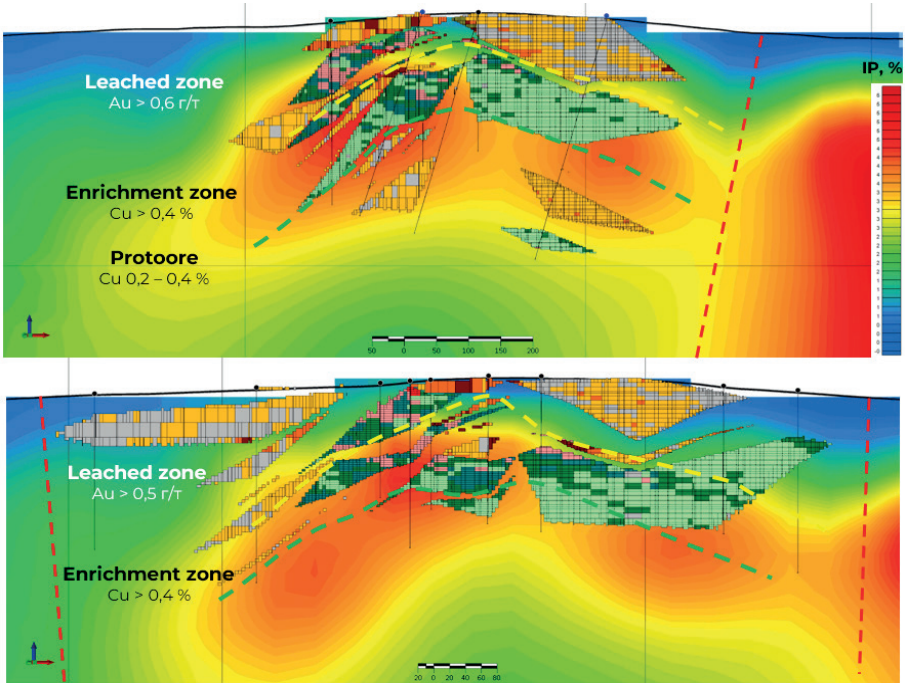


Figure 4- Cross-sections perpendicular to the strike of the main ore zone of the Sokyrkoy deposit, showing the morphology of supergene zonation areas (polarization model used as the background)

In addition to the secondary enrichment zone, more local areas were identified in the field structure, marked by intense subvertical anomalies of reduced resistance (up to 10-100 ohms* m) combined with a negative magnetic field (presumably a demagnetization zone). These sites are recorded starting from a depth of 400 m and are presumably associated with bodies of eruptive breccias (Sillitoe, 1985), which are ore channels for primary pyrite-chalcopyrite-bornite? mineralization (Fig. 5).

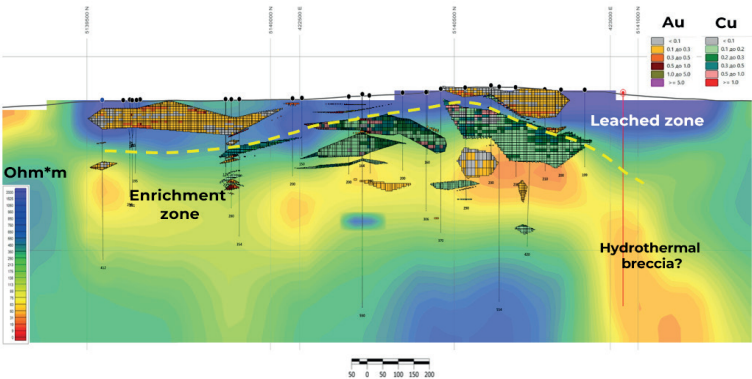


Figure 5- Longitudinal section perpendicular to the strike of the main ore zone of the Sokyrkoy deposit, showing the morphology of supergene zonation areas (resistivity model used as the background)

Based on a comprehensive interpretation of the geophysical data, a unified model of the Sokyrkoy deposit was constructed (Fig. 6). For ease of visualization and geological interpretation of the obtained geophysical data, graphs of the distribution of physical characteristics along the profile AB were constructed.

The presented diagram (Fig. 6) shows graphs of the distribution of apparent resistance (p , green line) and polarization (IP , red line) at various depth sections of the object (50 m; 200 m and 500 m from the surface) (Fig. 6A - C), in addition, combined graphs of the distribution of magnetic field values are presented. The fields (ΔT) and gravity fields (ΔG) (Fig. 6D), and a section of the apparent resistance field model is also shown (Fig. 6E) and a fragment of the geophysical interpretation scheme with a projection of the skeleton model of the gold-copper and copper mineralization of the deposit, positive magnetic field anomalies (interpreted as rod-shaped intrusive bodies of acid composition) and the main disjunctive disturbances developed within the deposit and its periphery.

The vertical zonation of the object is quite clearly observed in the diagram, expressed in a change in the nature of resistivity and polarization at its deep sections.:

- at a cut of 50 m (during modeling, it was found that this zone can be traced to depths of 100-150 m), the central part of the profile (the area of ore mineralization) is characterized by a reduced value of polarization and increased resistivity and corresponds to the metasomatites of the leaching and oxidation zone.

- at a cutoff of 200 m (during modeling, it was found that this zone can be traced to depths of 300-350 m), the nature of electric fields changes – increased polarization values and low resistivity correspond to the lower boundary of the secondary sulfide enrichment zone.

- at a 500 m cut, reduced electrical resistance values with fairly high polarization values can be interpreted as local bodies of primary sulfide mineralization ("protorud zone").

When compared with the generalized petrophysical model of the copper-porphyry deposit (Fig. 2), it can be concluded that the object under study generally corresponds to this model, both in terms of the presence of such elements of the ore-magmatic system as "ore (?) rods" and near-ore metasomatites, and in terms of its vertical zonality.

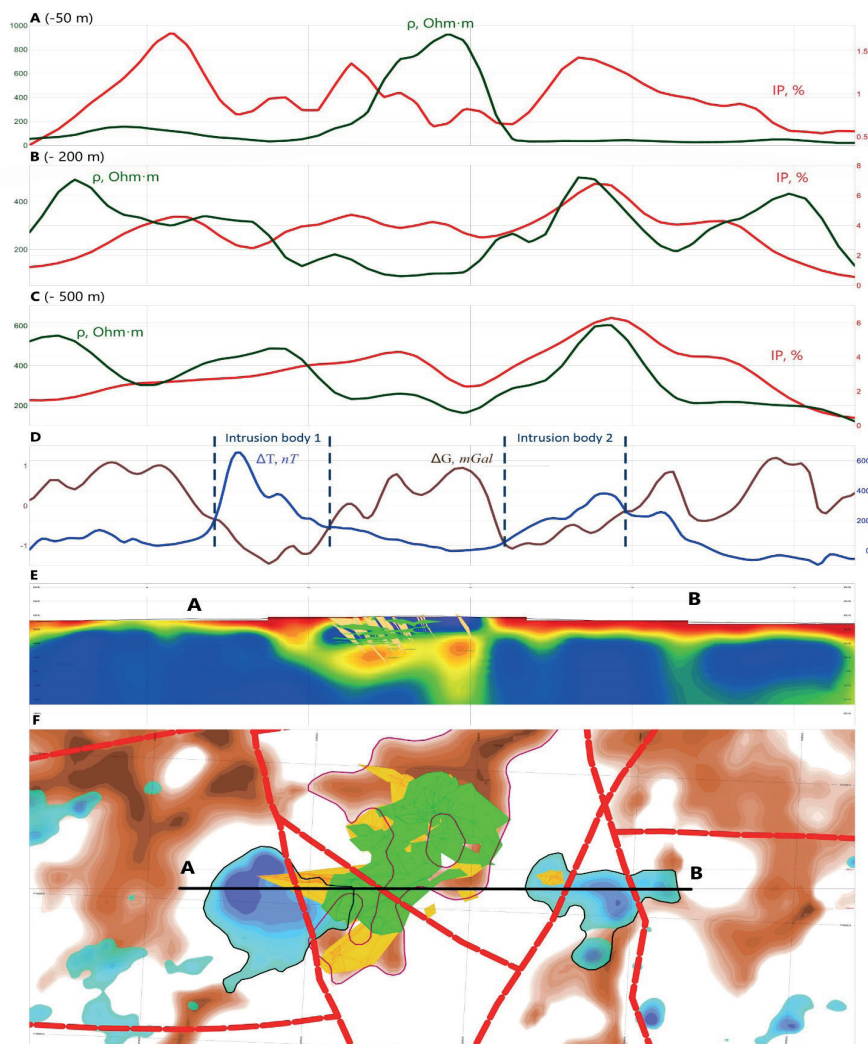


Figure 6- Scheme of integrated interpretation of geophysical data along profile AB of the Sokyrkoy deposit

Conclusion

1. A comparison of the obtained geophysical data on the territory of the Sokyrkoy deposit with the generalized petrophysical model of copper-porphyry deposits allows us to conclude that the object under study generally corresponds to the "reference" model. The results obtained substantiate the prospects for continuing exploration work, both within the field itself and through work aimed at identifying additional facilities within the peripheral parts of the Sokyrkoy ore field.

2. Based on modeling of physical fields and comparing the results obtained with geological data, a close relationship has been established between the position of the secondary sulfide enrichment zone and the roof of the resistivity field gradient

zone. This made it possible to clarify the morphology of the body of the secondary sulfide enrichment zone, which was previously interpreted as a subhorizontal body; at the moment, its arched morphology with wings sinking in the north-west and south-east directions has been established (Fig. 3). Thus, the morphology of the deposit, according to the results of geological exploration in 2023-2024, corresponds to its geological and structural position in the paleovolcanic structure. At the same time, in our opinion, the bulk of the exploration wells drilled in the central part of the field did not leave the zone of secondary sulfide enrichment and mixed ores, which significantly increases the prospects for building up the mineral resource base of the field.

3. In the northern part of the deposit, additional subvertical bodies of "secant" morphology have been installed in the electric fields of polarization and resistance, interpreted as bodies of eruptive breccias.

4. The results of the study confirm the high efficiency of integrating geophysical, geochemical and geological data when re-examining previously studied objects. This approach makes it possible to model ore bodies in a new way and with greater accuracy, which, in turn, helps to increase the ore potential of the deposit and significantly simplifies the planning of subsequent stages of exploration.

The direction of further work

At the moment, a work program has been prepared for the final drilling of the flanks of the gold anomaly identified during the lithogeochemical survey and the final drilling of low-resistance subvertical bodies in the northern part of the deposit.

Based on the results of modeling the Sokyrkoy deposit and analyzing lithogeochemical data, it was found that the bulk of the known gold mineralization is confined to the eroded part of the Sokyrkoy structure, which almost completely corresponds to the lithochemical area of the gold anomaly (>5 ppb). At the same time, in wells at depths of 150 m or more, outside the eroded part, under lava flows of andesites, exposed mineralized intervals of 0.3-0.5 g/t do not manifest themselves in an anomalous geochemical field, i.e. secondary gold halos do not capture the features of the geological structure of the Sokyrkoy deposit.

As a hypothesis, it is assumed that after its formation, the gold-copper mineralization was eroded, with the destruction of the upper parts of the mineralized zones, primary and secondary halos of scattering, and then again blocked by younger lava flows that "hide" the anomalous geochemical field of gold-copper mineralization.

In the current geological situation, in order to search for additional gold mineralization in the course of further work, it is recommended to use geochemical surveying methods capable of detecting mobile forms of metals during constantly occurring physico-chemical diffusion processes, for example, the ion-sorption analysis method.

In addition, the use of absolute dating methods is recommended, which will allow for a more accurate stratigraphic and age differentiation of the geological complexes composing the Sokyrkoy ore field and establish the sequence of their

formation. These data are necessary for constructing an ore model of the area both in its current state and in a dynamic aspect reflecting the stages of development of the facility, which, in turn, will create the basis for sound forecasting of new promising facilities within the entire coastal mineragenic zone.

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