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GEOPHYSICAL INDICATORS OF RARE-METAL ORE CONTENT OF AKMAI-KATPAR ORE ZONE (CENTRAL KAZAKHSTAN)

Purpose. Identification of geophysical criteria to determine ore content indicators within the territory relying upon systematization of both geological and geophysical materials.

Methodology. The research involved innovative techniques used in the field of geology, i.e. GIS technology, and such theoretical scientific approaches as analysis and synthesis of petrophysical data, and data of geophysical anomalies in the context of the analyzed ore zone.

Findings. Petrophysical characteristics of Akmai-Katpar ore zone rocks have been generalized and systematized. Petrophysical model of the ore zone has been developed; changes in petrophysical rock characteristics have been defined in terms of Silurian, Devonian, Carboniferous, and Permian systems. The obtained parameters of the petrophysical model are integrated with the identified geophysical anomalies. Geophysical indicators of ore content of the rare-metal ore zone have been determined. Cartographic documents have been specified which made it possible to perform layer-by-layer mapping of Akmai-Katpar ore zone.

Originality. For the first time, the systematized geological and petrophysical materials have been applied to build the petrophysical model of Akmai-Katpar ore zone and improve geophysical forecasting criteria.

Practical value. It consists in the use of geophysical forecasting criteria while identifying prospective areas where rare metals occur.

Keywords: *ore zone, rare metals, petrophysical characteristics, geophysical anomalies, gravity field, magnetic field*

Introduction. Kazakhstan is a large rare-metal province since its subsurface contains the main reserves of wolfram, molybdenum, and other rare metals. The key rare-metal deposits, being of industrial importance, are within the territory of Central Kazakhstan too [1, 2]. They include greisen-quartz vein deposits Verkhniy Kayrakty (wolfram), Koktenkol (molybdenum), and large stockwork deposits Baynazar, Batystau, Seltey, Yuzhny Zhaur, Zhanet and others. In practical terms, Akmai-Katpar ore zone occupies a special place since it contains skarn-greisen Severny Katpar deposit with complex molybdenum-wolfram ores as well as rare metal stockwork wolfram Akmai field, and a number of rare metal ore occurrences [3, 4].

Kazakhstan subsurface includes significant reserves of almost all major types of fuel-energy and metal minerals being a resource base of the modern industrial production [5, 6]. Wolfram reserves in Kazakhstan are the largest globally; in addition, the country ranks fourth as for molybdenum reserves. Almost 85 % of wolfram fall at stockwork ore (Verkhniy Kayrakty, Koktenkol, and Karaoba deposits); tungsten trioxide content is 0.12–0.19 % [7].

Against successes in geological sector, there are also problems with rare metals, i.e. depletion of their reserves [8, 9]. In this connection, replenishment of rare metal raw-materials base in the traditional ore areas with the developed infrastructure and human settlements is extremely topical problem being also the top-priority task of geological sector of our Republic [10, 11].

The main industrial deposit types of rare metals, being skarn-greisen, vein-greisen, and stockwork ones, are concentrated within Central Kazakhstan [12]. In the area, many rare-metal fields (e.g. Akshatau, Karaoba, Eastern and Northern Konyrat) have already been mined out; a part of them has been preserved due to low ore content (for instance, Baynazar, Batystau, and Zhanet deposits). The abovementioned is the main factor restricting their industrial development. Others are either poorly prospected or poorly studied fields [13].

Currently, skarn-greisen deposit *Severny Katpar* in Akmai-Katpar ore zone of Central Kazakhstan is important in practical terms [14, 15]. The ore area is in the central share of Uspensk depth movable zone on the border between Zhaman-Sarysuisk and Sarysuisk anticlinorias; its territory is about 22.5 square kilometers [16].

Late Permian Akmai intrusion of leukocratic granites has played the main role in the formation of rare-metal mineralization within the studied area [17]. Ore-bearing intrusion is interbedded along the long-lived Domeke-Kushuk fault; Akmai-Katpar ore zone is associated with its edge [18, 19]. The area is characterized by the Lower Tournaisian limestones covered by terrigenous deposits of Upper Famennian. Skarn-greisen formation has emerged within granite intrusions-carbonaceous rock contact [20]. According to geophysical data, ore-bearing Akmai intrusion took shape at a 1–3 km depth; it is of a linear solid form with 3 × 10 km geometry (Fig. 1).

The intrusion roof is at the depth of 400–600 m below the surface; its morphology is of a complex nature. It consists of a number of domes over which the known Akmai and Severny Katpar deposits are located as well as several ore occurrences being Zapadny Katpar, Severo-Vostochny Katpar, Bibigul, and Domeke (Fig. 2).

Severny Katpar deposit is in Shet District of Karaganda Region 12 kilometers east of a railway station Zharyk, and 25 kilometers north of Verkhnie Kayrakty ore mining and processing enterprise. It is in the central axial part of Uspensk synclinorium consisting of Late Hercynian volcanogenic sedimentary formations of island arcs and carbonate sedimentary deposits of central rift depressions. Severny Katpar is rather compact field, which helps apply open pit mining. If average tungsten trioxide content in the deposit ore is 0.24–0.25 % then use of preliminary preparation makes it possible to get rid of up to 40–50 % of waste rock (i.e. limestone) and obtain pre-

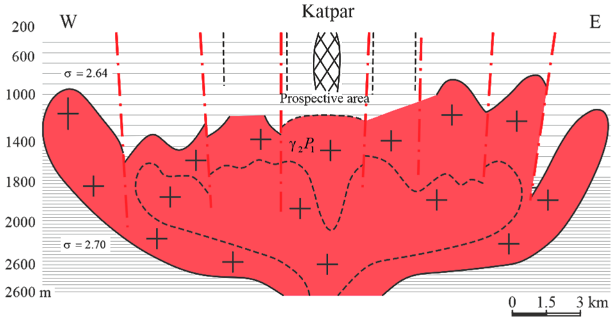

Fig. 1. Schematic geological and geophysical cut of the metalliferous rock mass (according to geophysical data by A. T. Burtubaev, 1977)

concentrate with up to 0.7–1 % tungsten trioxide content. A comparatively simple preparation procedure. favourable economic conditions, rather high-grade ore, and capital expenditures for the development are the factors in terms of which Severny Katpar field has the advantage over other wolfram deposits in Central Kazakhstan [21, 22].

Akmai deposit is 50 kilometers northeast of a railway station Agadyr. The field is connected with a limestone unit occurring under quartz-sericitic and clayey shale [23]. Within the area, the shale experienced partial metamorphism; it became hornfelsed partially. Cherts and shales shape small lenses alternating with less changes limestones and shales. Mainly, the key ore field is concentrated in a limestone formation member. Despite the fact that reserves of the deposit are not large, it remains underexplored at deep levels due to intrusive granite of leucocratic composition prospected at a depth of Akmai intrusion [24, 25].

Rare-metal deposits as well as mineralizations of Akmai-Katpar ore zone were studied by several generations of geologists and geophysics starting from the 1940s [26]. Geological archives contain numerous paper-based factual data as well as cartographic documents. They involve geological maps, maps of geophysical fields inclusive of gravitational and magnetic data, and topographic maps and schemes of cuts belonging to the mentioned fields within the ore zone [27, 28].

For the moment, the research group has scanned the materials and connected them with geographical coordinated of the deposits. Accordingly, GIS program was applied. Digital geodata base has been developed corresponding to the interna-

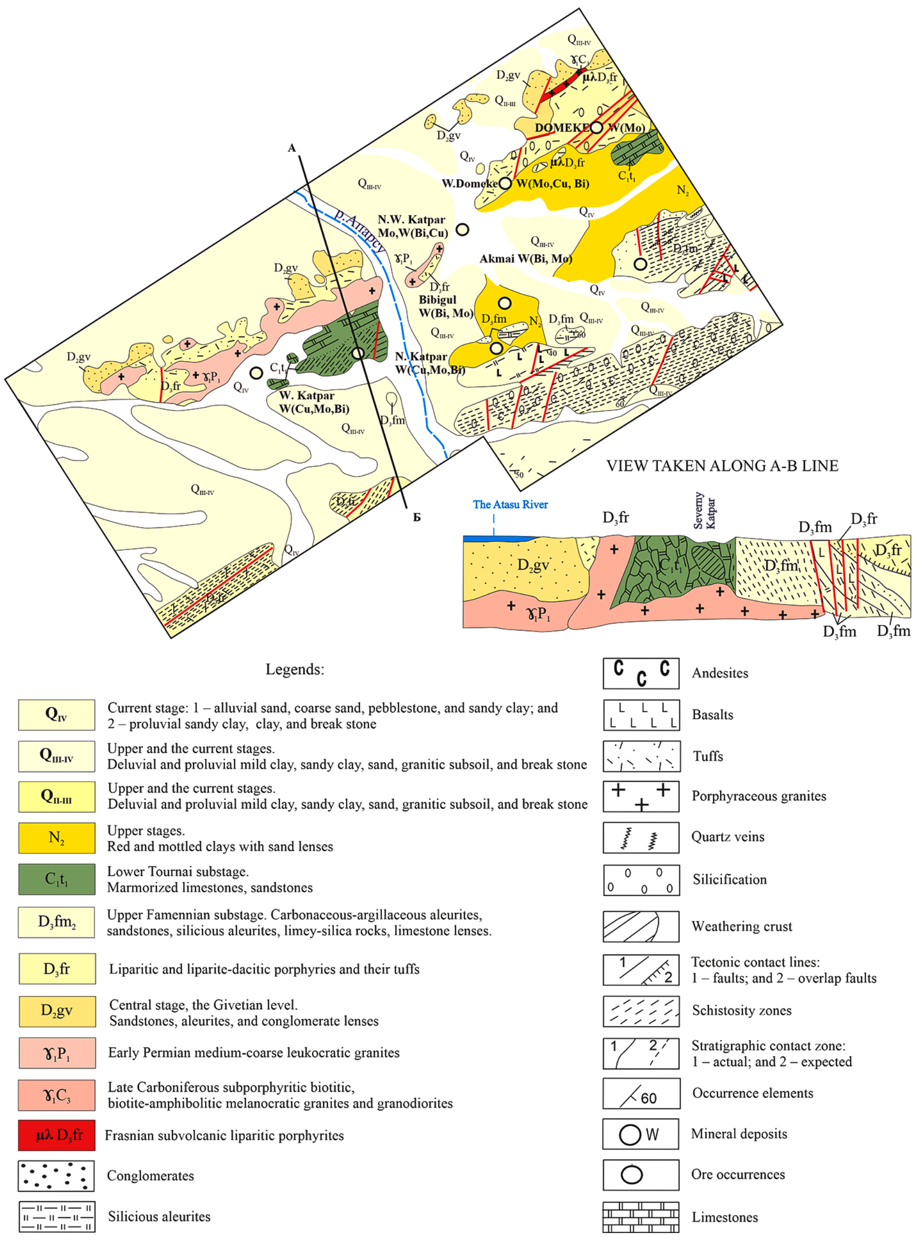

Fig. 2. Map of geological structure of the ore zone Akmai-Katpar (Agadyr GPE, 1993 with supplements of 2023)

tional information standard used globally. The digital base has made it possible to build 3D digital models of rare-metal deposits Katpar and Akmai using software program Micromine. The abovementioned has helped them forecast more confidently the hidden mineralization and solve practical problems concerning identification of prospective areas both within the deposits and at their flanks [29].

Moreover, the digital geodata basis has helped build dynamic formation models of the deposits solving some theoretical problems of rare metal mineralization as an assessment of their shaping period.

It should be mentioned that geological materials, accumulated by different generations of the experts, are widely used for the modern scientific studies. Nevertheless, the abovementioned is not applicable for geophysical materials from the Republic funds (it concerns materials of Adagyr geophysical expedition). In this context, it should be noted that currently the enormous factual geophysical material is not applied to solve practical geological problems.

In turn, it complicates following applied research:

- determination of geophysical criteria to forecast rare metal mineralization;
- identification of structures and areas being favourable to prospect rich in content but blind rare metal objects.

Hence, the main research purpose is systematization of petrophysical data to build petrophysical model of Akmai-Katpar ore zone, and tie the petrophysical rock characteristics with the observed geophysical anomalies for determination of geophysical features of rare metal mineralization of the abovementioned ore zone.

Materials and methods. Successful solving the problem involved both analysis and structurization of geological and geophysical data connected with the ore zone. In this vein, a system-based scientific approach to geological and geological information has been applied which helped divide them into the three groups:

I. Geological information. As part of Akmai-Katpar ore zone analysis, following geological formations have been studied and classified (Fig. 1) [30, 31]:

- sedimentary and ingenious bodies dating from the Lower Silurian;
- effusive rocks formed during the Lower and Middle Devonian;
- ingenious structures of the Upper Paleozoic;
- complex of various sedimentary and sedimentary-igneous rocks available in the Upper Devonian and Lower Carboniferous;
- intrusive rocks distributed within the northern part of the ore area inclusive of alaskitic granites composing Akmai formation; the rocks have been studied through well drilling at 400–600 m depths;
- deposits belonging to tertiary and quarternary periods.

Sedimentary and carbonaceous rocks are observed within the central share of the ore zone. They are the Upper Famennian aleurites and sandstones (D_3fm_2) and the Lower Tournaisian limestones (C_1t_1). Near Severny Katpar deposit, limestones are affected by metamorphism processes. To the north of the field, less metamorphized their differences are exposed (Fig. 1).

II. Petrophysical characteristics (i.e. density, magnetic susceptibility, magnetism, and apparent resistivity). Petrophysical characteristics of the area rocks are based upon monographic and reference data as well as production reports from the 1980s till 2018. Such petrophysical characteristics as density and magnetic susceptibility have been systematized for Akmai-Katpar ore zone helping conclude the following:

1. The rocks considered within the ore zone can be divided into four groups depending upon their density.

Group one contains intrusive formations of all complexes with less than 2.55–2.57 g/cm^3 density.

Group two contains efffusive rocks of subvolcanic facies of liparitic carbon porphires with 2.57–2.62 g/cm^3 density.

Group three contains liparitic rocks as well as tuffs, corresponding to them, and belonging to the Middle and Lower Devonian, and carbonate rocks, belonging to the Carbon which density is 2.64 to 2.68 g/cm^3.

Group four contains following types of formations and rocks with 2.70 up to 3.5 g/cm^3 density: igneous bodies; marmorized limestones, belonging to the carbon; andesite porphyrites; skarn-greisen units; and stockworks formed during the Silurian period.

2. Magnetic rock characteristics in Akmai-Katpar ore zone help separate such three groups. Group one involves such nonmagnetic rocks as carbonate-terrigenous deposits of the Lower and Upper Famennian; piroclastic bodies of liparite-dacitic composition; subvolcanic facies of liparitic porphyritis; and igneous Devonian formations. Their magnetic susceptibility is $12–15 \cdot 10^{-6}$ CGS.

Group two involves rocks with low magnetic activity being liparite-dacitic porphyrites, and leucocratic composition granites which magnetic susceptibility is 60 up to $120 \cdot 10^{-6}$ CGS.

Group three involves such magnetic rocks as andesite porphyrites with $3840 \cdot 10^{-6}$ CGS magnetic susceptibility, and the Silurian and Middle Devonian hornfelsed bodies; the Permian and Carbon biotitic granites which magnetic susceptibility is 240 up to $960 \cdot 10^{-6}$ CGS.

From the viewpoint of electric characteristics, rocks within deposits and mineral occurrences of the ore zone demonstrate high level of electric resistivity. It is especially important to mention intrusive and effusive rocks where electric resistivity is 1500 up to 3000 OHMM.

In terms of rock polarizability, the Devonian and Carbon minerals are almost similar since their metal factors are within analogous ranges being 1.3 to 1.66 %. Nevertheless, it should be mentioned that polarizability of the Permian granites is much higher (i. e. 2.8 %) to be twice as much as the Devonian and Carbon rocks.

III. Geophysical anomalies. In the context of Central Kazakhstan, there are some similarities between mineralogical ore composition as well as morphology of ore bodies. Relying upon analogous nature of polarizability of the Devonian and Carbon rocks, analysis of ore contain rate in the rare features may result in the fact that physical fields will demonstrate identical characteristics. The anomalies may cover the areas with negative minimums of gravity fields as well as areas with positive magnetic disturbances.

The features are helpful while identifying potential deposits of rare metals within the considered ore zone.

Analysis and synthesis of geophysical materials in Akmai-Katpar ore zone as well as GIS technology to process cartographic data have become the basic research approach.

Research and discussion. *Petrophysical model of Akmai-Katpar ore zone.* The collected and systematized data, concerning petrophysical rock characteristics, have made it possible to build petrophysical model of Akmai-Katpar ore zone (Fig. 1). Subsequently, analyze petrophysical characteristics of the ore zone rocks.

Density. Ingenious rocks, corresponding to the Silurian period, are of density within the range of 2.78 g/cm^3.

The Middle Devonian D_3Fm_2 minerals are effusive acidic rocks (i. e. liparitic and liparite-dacitic porphyres) with 2.59–2.64 g/cm^3 density. The Middle Devonian rocks of the Famennian stage D_3Fm_1 are andesites differing in slightly higher density values, i.e. up to 2.70 g/cm^3. Density of such piroclastic formations of liparite-dacitic composition as Givetian D_2gv and Frasnian D_3Fr, belonging to the Devonian, is 2.58 to 2.70 g/cm^3. It should be mentioned that in the Devonian profile, density of enclosing rocks increases.

Density of the Carbon rocks of the Tournai stage C_1t_1, (i. e. limestones and marmorized limestones) is 2.64 to 3.5 g/cm^3. Relatively high density value corresponds to the marbleized dark gray limestones with obvious sulfide impregnation.

Table 1

Petrophysical model of Akmai-Katpar ore zone

Erathem	System	Stage	Age index	Column	Thickness	Rock description	Density, g/cm^3	Magnetic susceptibility, $\varkappa = 10^{-6}$ GHS
Cainozoic	Neogene	Miocene-Pleiocene	N1-N2		< 45	Red and mottled clays with sand lenses	–	–
	Paleogene	Eocene	$₽_3$		< 5	Sand, coarse sand	–	–
	Permian	–	γP_1		–	Early Permian granites	2.55	60
Paleozoic	Carboniferous	Tournaisian	C_1t_1		200–300	Limestones Marmorized limestones	2.64 2.70–3.5	12
			γC_3 $\gamma\mu C_1$		–	Biotitic granites Andesite porphyrites	2.57 2.78	240 3840
	Devonian	Famennian	D_3Fm_2		880–1140	Siliceous aleurites Limey-siliceous rocks Limestone lenses	2.58 2.68 2.64	13 10
			D_3Fm_1		400–500	Effusive andesites	2.70	65
		Frasnian	D_3Fr		2000–2700	Liparitic porphyres Liparite-dacitic porphyres Their tuffs	2.64 2.68 2.59	12–15
		Givetian	D_2gv		650–800	Sandstones Aleurites Conglomerate lenses	2.58 2.67 2.70	29 16
	Silurian	–	S_2		>1000	Igneous rocks	2.78–2.84	960

Density of the Carbon limestones (2.64 g/cm^3) is almost similar to the Devonian rock density. High values of the minerals are characteristic to their varied differences. In terms of the profile, carboniferous biotitic granite is a low-density rock since its density is 2.57 g/cm^3; moreover, andesite porphyrites have a high density value being within 2.78 g/cm^3.

The Permian granites are rocks with the lowest density (2.55 g/cm^3); deposits and a number of mineralizations in the ore zone are associated with them.

The petrophysical model helps understand that there are no specific changes in the density characteristic of the ore zone. It should be mentioned that a clear difference has been observed in density characteristics of intrusive formations (i.e. the Upper Carboniferous and Permian granites) having almost 2.55 g/cm^3 density and being characterized by sedimentary bodies of silurian and carbon which density is 2.64 up to 2.77 g/cm^3. The abovementioned makes it possible to use the density rock characteristics while identifying intrusive formations occurring within the area and containing rare metals. Hence, the considered ore zone involves variety of rocks differing in density. The density characteristics may be applied for geological studies as well as for rare-earth metal prospecting.

Magnetic susceptibility. It should be mentioned in this vein that enclosing rocks of Akmai-Katpar ore zone vary considerably as for their magnetic susceptibility. The characteristics may vary over a wide range of values from $10 \cdot 10^{-6}$ up to $3840 \times \times 10^{-6}$ CGS. The aforementioned denotes diversity of magnetic rock characteristics in the zone and emphasizes the importance to take into consideration the data in the process of geological studies and analysis of ore deposits.

As the petrophysical model demonstrates, the hornfelsed indigenous silurian rocks are of high density as well as high magnetic susceptibility within $960 \cdot 10^{-6}$ CGS depending upon the exocontact metamorphism processes resulting in the increased magnetic susceptibility of rocks. Magnetic susceptibility of effusive Devonian and Carbonic rocks results from the variety of their lithological composition as well as different morphogenetic demonstration types inclusive of lava material, subvolcanic bodies, tuffs, and other rock varieties. Its value varies in the range of $12–100 \cdot 10^{-6}$ CGS. Within the ore zone, andesite Carboniferous porphyrites have the highest magnetic susceptibility value being $3840 \cdot 10^{-6}$ CGS. In addition, biotitic Carboniferous granites also have relatively high magnetic susceptibility value, i.e. $240 \cdot 10^{-6}$ CGS. Magnetic susceptibility of the Carboniferous limestones is $12 \cdot 10^{-6}$ CGS. Consequently, it is possible to conclude that within the ore zone, the Carboniferous profile is characterized by $12 \cdot 10^{-6}$–$3840 \cdot 10^{-6}$ CGS changes in magnetic susceptibility; as for the Devonian profile, it differs in its relatively low value being $10 \cdot 10^{-6}$ up to $65 \cdot 10^{-6}$ CGS.

It is important to stress that analysis and classification of petrophysical rock characteristics of the analyzed ore zone cannot be an independent mission; it should be correlated with the analysis of the observed geophysical fields. In this connection, we performed digitization and GIS-Micromine binding of cartographic materials of Akmai-Katpar zone in identical scope (geological, geophysical, etc.). As a result, layer-by-layer 3D maps have been obtained for the study area where gravitational and magnetic anomalies over it are visualized below.

Gravity field. Analyze correlation between petrophysical rock characteristics and nature of geophysical fields in Akmai-Katpar zone (Fig. 3).

According to the geophysical data, granite bodies with rare-metal mineralization differ in negative gravity anomalies. Their characteristics are defined through geometry, depth, density of intrusive formations as well as density of surrounding rocks and their vertical thickness.

Geological data in the ore zone show Katpar and Akmai granite formations with low 2.55–2.57 g/cm^3 rock dense chartics. In this connection, we consider the conditions for Akmai-Katpar ore zone.

According to the data by researchers, petro-density characteristics of rare-metal bodies (i.e. stockworks, skarns, and greisen masses) as well as igneous-sedimentary rocks in Central Kazakhstan differ slightly from each other. Consequently, they are not anomalous since disparity between their density characteristics is minor. Nevertheless, a difference between density characteristics of metalliferous granites and igneous-sedimentary rocks is obvious as the result of low density of granite intrusions. Such a regularity remains unchanged for Akmai-Katpar ore zone where analysis of its petro-density characteristics has made it possible to assess negative excessive density initiating gravity anomaly being 0.3 g/cm^3 for densities of enclosing rocks (2.65–2.84 g/cm^3) and ore-bearing granites (2.55 g/cm^3).

In this regard, developmental nature of the gravity field within Akmai-Katpar ore zone is as follows:

- metalliferous granitoids of Akshatau complex of the ore zone are characterized by negative gravitational anomalies. Gravity field is calm; relatively small anomalies (i.e. 0.2–0.3 Mgal) depend upon tectonic as well as disturbances of the domed structures of the granite formation associated with the deposits and ore occurrences;
- skarns and greisens of the ore zone are characterized by positive low-amplitude gravity anomalies.

Developmental nature of a *magnetic field* of the ore zone is as follows:

- the Carbonic and Permian granitoids within Akmai-Katpar ore zone are characterized by positive values of a magnetic field;

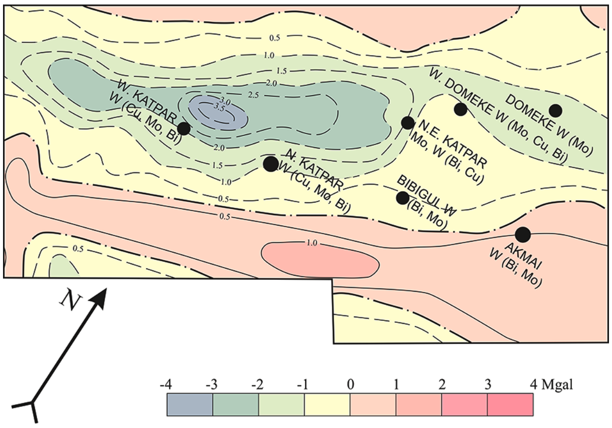

Fig. 3. Isoline map of gravity anomalies within Akmai-Katpar ore field

acteristics. As a result, they become apparent in the gravity field as a single gravity minimum in the form of a regular ellipsoid structure with 0.2 to 0.3 Mgal intensity; the field is oriented north-easterly. The gravitational minimums correspond to the domed patterns of the granite formations (Fig. 2).

The Devonian rocks with 2.65–2.68 g/cm^3 density favour origination of positive gravitational anomaly being within the range of 0.2–0.4 Mgal.

Density of marble rocks, being the recrystallized carbonate Carboniferous bodies and occurring within a contact zone with the Permian granites, is 2.70 to 2.72 g/cm³. The rocks initiate positive gravitational anomaly which intensity achieves 0.4 Mgal. Moreover, positive gravitational anomaly with 0.3–0.4 Mgal intensity is also observed in the neighbourhood of Akmai deposit; it is connected with hydrothermally hydrothermal altered rocks.

Generally, Akmai-Katpar ore zone is characterized by negative gravitational anomaly at the expense of low-density intrusive rocks. Nevertheless, of metamorphism and metasomatism will influence changes in rock density; hence, they result in positive gravitational anomaly.

Magnetic field. At the northern border of Akmai-Katpar ore zone, tension stress and deep subsidence areas, controlling such places, have demonstrated narrow zones of negative gravitational anomalies with 50–150 nT intensity. Some faults, cured dykes of intrusive rocks of average and main compositions, and shallow differentiates of the Permian intrusions have demonstrated positive magnetic anomalies with 100–200 and more nT intensity. Magnetic susceptibility of the intrusive rocks varies from 60 · 10^{-6} up to 240 · 10^{-6} CGS. It should be mentioned that northern border of the ore zone is the gradient one. Southern border of the ore zone shows down to 0 attenuation of negative magnetic anomaly. It depends upon the fact that the Devonian ingenious-sedimentary deposits contact with terrigenous sediments of the stage of the Lower Silurian.

Supraintrusive zone of Akmai intrusion, where rare-metal objects are concentrated, stands out thanks to its positive magnetic anomalies which intensity is 50–200 nT. Within Severny Katpar and Akmai deposits, intensity of positive magnetic anomalies drops down to 50 nT depending upon low magnetic susceptibility of carbonaceous rocks not exceeding the value (Fig. 4).

Geophysical anomalies (i.e. gravitational and magnetic) of Akmai-Katpar ore zone correlate with the geochemical anomalies (Fig. 5).

In such a way, the maps support the idea that deposits and occurrences of the ore zones are concentrated within the areas where geochemical anomalies coincide with gravimagnetic anomalies (Figs. 3, 4 and 5).

It is common knowledge that prognostic-prospecting geophysical criteria are the features of anomalous geophysical fields and their relation with petrophysical rock characteris-

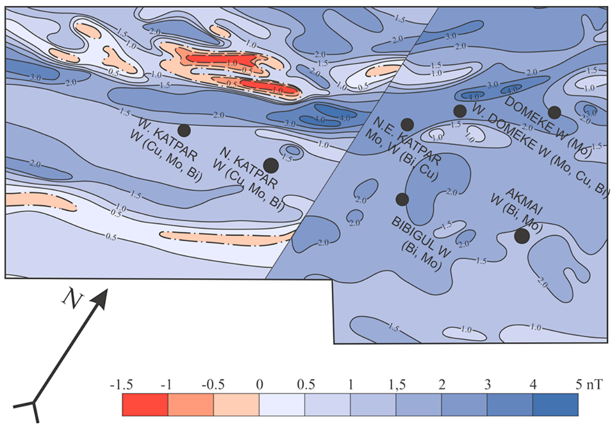

Fig. 4. Map of isodynamic lines within Akmai-Katpar ore zone

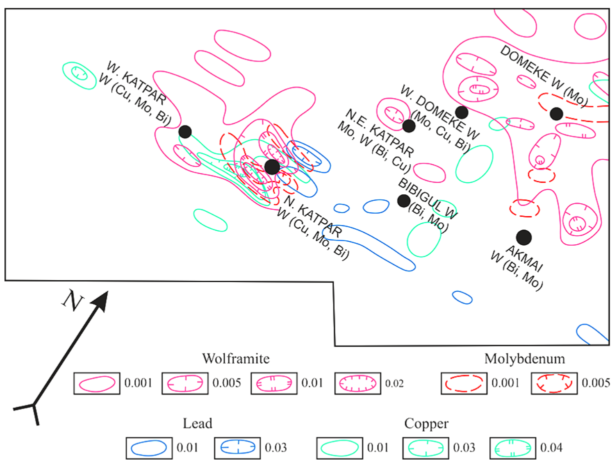

Fig. 5. Map of geochemical anomaly within Akmai-Katpar ore zone

- despite the age, sedimentary formations are characterized by negative values of a magnetic field;

- zones of such ingenious-piroclastic Givetian-reside-Frasnian formations as liparites, liparitic dacites, and andesite dacites are characterized by the abruptly variable magnetic fields;

- zones of the scarnified rocks are characterized by positive values of a magnetic field;

- Skarn-greisen ore bodies differ in weak magnetic susceptibility being $50 \cdot 10^{-6}$ CGS; however, mineralogy of Katpar field shows magnetite as one of the basic minerals. Nevertheless, its content is not more than 1 %. In such a way, weak magnetic anomalies take place.

Analysis of geochemical and geophysical anomalies as well petrophysical models in the synthesis with geological data formed the basis to identify geophysical indicators of rare-metal ore content of the territory in the form of:

1) determination of intrusive bodies with following petrophysical characteristics being the reduced density (i. e. 2.55–2.57 g/cm^3), and low magnetic susceptibility (i. e. $50-100 \times \times 10^{-6}$ CGS);

2) combination of zones of negative gravitational minimums and zones of positive magnetic anomalies with geochemical anomalies.

Hence, the potential of Akmai-Katpar ore zone is determined by Akmai intrusion of leucocratic granites since it has genetic relationship with all fields and occurrences of the ore zone associated with its domed structures; moreover, mineralogical ore compositions within them are also similar. It is known that only one share of the ore zone has been prospected which is associated with the largest blind dome; smaller domes are located easterly and westerly. Eastern part of the intrusion has been prospected best of all; Katpar Severo-vostochny and Bibigul sites have been explored. Prospective geophysical anomalies, associated with smaller domes, have been identified. At the same time, the western portion of the buried Akmai intrusion remains unstudied; nevertheless, numerous combined gravimagnetic and geochemical anomalies are registered. Such areas within Akmai-Katpar zone are promising from the viewpoint of indication of rare-metal ore objects.

Conclusions. The findings, represented by the paper, are based upon the analysis of geophysical, geochemical, and petrophysical data. They help draw conclusions on the prospects of rare-metal ore content within Akmai-Katpar ore zone. Geophysical and petrophysical rock characteristics of Akmai-Katpar ore zone are important to identify ore-bearing potential of the territory.

Petro-density characteristics of rare-metal bodies as well as ingenious-sedimentary rocks can be similar which prevents from gravity anomaly initiation; nevertheless, comparatively low density of granite intrusions results in negative gravity anomalies to compare with enclosing rocks. At the same time, the gravity anomalies depend upon rock types and structural features. As a rule, ore-bearing granitoids have negative gravity anomalies by comparison with skarns and greisens demonstrating weak positive anomalies.

Development of magnetic fields depends upon the rock types and petrophysical characteristics. Granitoids differ in positive values of magnetic fields. In turn, ingenious-sedimentary formations are negative; and the skarned rocks are positive.

Analysis of geochemical and geophysical anomalies as well as petrophysical data has made it possible to identify geophysical indicators of rare-metal ore content inclusive of intrusive bodies with characteristic petrophysical features, and combination of gravitational and magnetic anomalies with geochemical disturbances.

The potential of Akmai-Katpar ore zone is determined by the availability of Akmai intrusion of leucocratic granites connected genetically with ore deposits. Despite the fact that the western share of the intrusion is unstudied, it is also promising from the viewpoint of rare-metal ore bodies.

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Геофізичні ознаки рідкометалевої рудоносності Акмая-Катпарської рудної зони (Центральний Казахстан)

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Мета. Встановлення геофізичних критеріїв щодо визначення ознак рудоносності території на основі систематизації геологічних і геофізичних матеріалів.

Методика. При проведенні наукових досліджень нами були застосовані інноваційні методи, що використовуються в галузі геології – ГІС-технологія, а також теоретичні наукові методи – аналіз і синтез петрофізичних даних і даних геофізичних аномалій щодо вивченої рудної зони.

Результати. Узагальнені й систематизовані петрофізичні характеристики порід Акмая-Катпарської рудної зони. Побудована петрофізична модель даної рудної зони й визначені зміни петрофізичних характеристик порід у розрізі наступних систем: силур, девон, карбон і перм. Отримані параметри петрофізичної моделі пов'язані з виявленими геофізичними аномаліями. Установлені геофізичні ознаки рідкометалевої рудоносності рудної зони. Уточнені картографічні матеріали, що дали змогу побудувати пошарові карти Акмая-Катпарської рудної зони.

Наукова новизна. Для побудови петрофізичної моделі Акмая-Катпарської рудної зони та удосконалення геофізичних критеріїв прогнозування вперше використані систематизовані геологічні й петрофізичні матеріали.

Практична значимість. Полягає у використанні геофізичних критеріїв прогнозування виділення перспективних площ зосередження рідкісних металів.

Ключові слова: *рудна зона, рідкісні метали, петрофізичні характеристики, геофізичні аномалії, гравітаційне поле, магнітне поле*

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