TO THE PROSPECT OF USING UNDERGROUND GRAVITY EXPLORATION IN DETECTING MINERALIZATION AROUND MINE WORKINGS

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Abstract. *This article describes the methodology and results of the application of underground gravity exploration in the study of polymetallic mineralization around the mine.*

Based on the features of changes in the nature of gravitational anomalies, ore bodies located both above and below the mine workings were identified, the possibilities of underground gravity exploration when searching for disturbing bodies in the near-worked space, the technique of underground measurements of gravity field elements, processing of observation results and methods for identifying local anomalies, the technique of interpretation of gravitational anomalies taking into account the conditions of mining. Specific examples show the geological efficiency of underground gravimetric studies in various physical and geological conditions when solving prospecting and exploration tasks.

When setting up gravimetric work on deposits of the contact-metasomatic type, the main task is to establish the possibility of high-precision gravimetric survey of ore bodies, to clarify complicating factors and the necessity of their accounting.

A feature of the distribution of a polymetallic deposit is the complexity of its formation both in depth and horizontally. According to the results of the autopsy of the bodies, there is a frequent alternation of relatively rich and poor ore bodies. Basically, the ore bodies have a columnar shape and have a steep declination of the south-eastern direction.

Keywords: *underground gravity exploration, mining, polymetallic mineralization, rock density, gravitational anomaly, corrections of the gravitational field, interpretation of anomalies.*

Introduction: Currently, mining at great depths requires the improvement of known research methods, but also the development of methods based on new scientific concepts. In this regard, in the 90s of the last century, the foundations of mine-well geophysics were formulated, the complex of which included the method of underground gravity exploration. The advantage of underground methods is that geophysical observations are carried out directly on ore objects or near mineralization. In this aspect, ore bodies behave as a source of geophysical fields, and they manifest themselves clearly by anomalous changes in the studied geophysical fields. On the other hand, the behavior of geophysical fields clearly reflects ore bodies that are not exposed by mining workings. They are of great interest from the point of view of identifying additional reserves of mineralization of the studied deposit.

During this period, deep horizons are being developed on the territory of Uzbekistan for the purpose of mining, which requires the use of more informative methods to assess the behavior and distribution of ore formations with depth. In this aspect, the use of underground gravity exploration is of particular interest, since ore mineralization is characterized by excessive density relative to the host rocks of the geological environment. However, the application of the method of underground gravity exploration requires solving a number of tasks according to the methodology of field work and interpretation, as well as geological interpretation of the results obtained from the point of view of mineralization detection [1,2]

2. Materials and methods

The work was carried out taking into account all the recommendations presented in the works on underground gravimetry by E.A.Mudretsova and her followers. On all ground (above the points of the corresponding mine workings) and underground gravimetric profiles, a network of support points was broken. In order to obtain more reliable results, the distance between neighboring OP was 75-100 m. Between them were the points of the ordinary network (RP with a step of 5-10 m). Measurements at the reference points were carried out using two competing methods: the closed–loop method (0 – 1 -2. -. n -n -...2 – 1 – 0) and cyclic measurements (0 – 1 - 0 – 1 – 2 – 1 – 2 -3 -...)

Ordinary measurements were carried out according to the reverse stroke method (from OP 0 to OP 1 and back to OP 0). With such measurements and on short flights, the zero-point slide

in most gravimeters was close to linear, which made it possible to neglect the influence of lunar-solar attractions and take into account their influence as a general correction for the displacement of the zero-point of the device. The work was carried out by various types of gravimeters (GRK-2 and GNU-KS). OP 0 points were common for ground and underground gravimetric surveys.

Simultaneously with the gravimetric work in all mine workings, and partly on the surface, samples of rocks and ores were taken in order to determine their average density, the data of which were later used to calculate various corrections and calculate the σeff necessary for the interpretation of the identified anomalies. Sampling weighing 150-500 g was carried out from the walls of the mine workings, approximately from the height of the location of the sensitive element of the gravimeter. The density of rocks and ores was determined by the method of hydrostatic weighing on technical scales. The measurement accuracy, determined by the magnitude of the RMS error, was 0.011 g/cm3. The density of rocks and ores varies from 2.1 to 5.55 g/cm3. According to the average cross sections on the studied area, the sweating of rocks is divided into two groups:

1. 2.64 – 2.69 g/cm3 – granitites and limestone.
2. Above 2.7 g/cm3 – quartz porphyries and diorites. Skarns and hydrothermally altered rocks have an average density of 3.0 – 3.1 g/cm3. Their excess density in relation to the host rocks is 0.3 – 0.4 g / cm3. The average density of polymetallic ores is 4.19 g/cm3, and their excess density relative to the host rocks is 1.4 – 1.5 g/cm3.

By determining the values of the density of rocks and ores, regular distributions of the density of rocks were revealed, which served as the basis for the interpretation of field observation data.

The processing of the results of gravimetric surveys was carried out by introducing a number of corrections to the measurement results (for the terrain using 16–ray Mudretsova pallets) with an averaging radius of up to 3 km, taking into account the influence of the near (scale 1: 1000) and far (scale 1: 25 000) zones of influence, Bug corrections and for the relief of mine workings. With quantitative interpretation, the depths of the center of gravity of bodies (hc) were calculated by curves (Δg) using the methods of E.G.Bulakh, D.S.Mikov, Andreev –Sokolovsky. Along with this, approaches were used to interpret the results obtained based on a three-dimensional model of the studied mineralization around the mine workings [6].

Underground field gravimetric studies were carried out at the Karamazarsky ore field, where the objects of study differed in physical and geological conditions. As an example, let's consider the results of field research at the Kantash field. The Vostochny Kantash deposit is located in the central part of the limestone ridge composing the axial part of the Kyzyl-cheku ridge, and is confined to the southern contact of limestones with granitoids. From the south, the limestone ridge is in contact with the Kuramin batholith, composed of granodiorites, diorites, and granodiorite porphyries. From the north, a layer of effusions of the Akchinsky formation, represented by dacite porphyries, lavobreccias of andesitodacite porphyrites, quartz porphyries, lies on the limestone with disagreement.

Scarns are formed along the southern contact of the ridge with an array of granodiorites and with numerous dikes of granodiorite porphyries. Garnet, pyroxene and mixed differences stand out among the scarns. Both garnet and pyroxene skarns are almost universally interspersed with sphalerite, galena, pyrite, however, polymetallic ore bodies are formed in skarns only in the contact areas affected by violations. In limestones, small, 1.5 - 2.0 m2, columnar ore bodies are sometimes formed at the intersections of cracks. In addition, there are interplastic deposits of ore bodies at a depth of.

The morphology of ore bodies is complex. The ore bodies of the deposit are composed of galena, sphalerite, pyrite and chalcopyrite. Chemical analyses of combined samples for ore bodies give on average (in %): 0.09 copper, 0.002 cobalt, 0.062 bismuth, 0.0002 tellurium, 0.109 cadmium, 0.35 g/t gold and 104.62 g/t silver.

3. Results

On the horizon of tunnel 11 (Fig. 1), the ore body "Sentralnoe 1" is represented by garnet-pyroxene skarns with rich inclusions of galena and sphalerite and is localized in limestones almost completely replaced by skarns. It has a shape close to isometric, with gradual wedging in the fall and rise. The maximum vertical power is 19.02 m, the average is 8.94 m, the average lead content is 3.21% zinc 2.28%. The ore body "Sentralnoe 2" was opened by the drift 3 of the tunnel 11, a number of surface and underground wells. The body shape is lenticular. The fall is northwest at an angle of 20-300. The ore body "Sentralnoe 3" was opened by a drift of 3 tunnels with 11 dissections and drilling wells. The body shape is complex, lenticular. The fall is north-northwest at an angle of less than 450, composed of garnet-pyroxene skarns interspersed with sphalerite, galena, pyrite. Average power 3.42 m. The average lead content is 2.20% and zinc 5.93%.

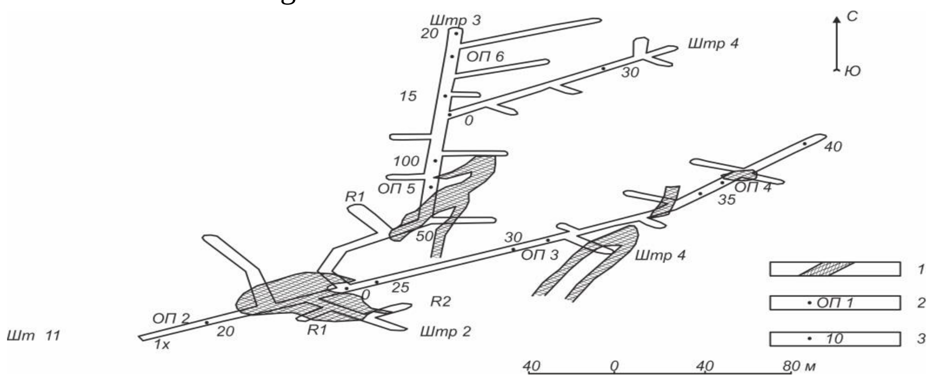

Fig.1. Vostochny Kantash. The plan of the tunnel 11 with the marked points of gravimetric observations. 1 – ore bodies; 2- points of the reference network; 3 – points of observation of the ordinary network.

At the Vostochny Kantash site, gravimetric observations were carried out on the surface, in tunnel 11 and drift 3.

The ground profile is passed from the southwest to the northeast, along the projection line of underground points on the daytime surface, the profile length is 400 m, the step is 10 m. The observed value drops sharply from PC 0 to PC 20. Starting from PC 20, there is an increase in gravity, the anomalous value of which is noted up to PC 37. At the end of the profile on PC 38-39, there is a slight deviation from the general slope of the curve in the direction of increasing Δg. After the introduction of corrections for the influence of the relief, within a radius of 3 km, the curve (Δg) corrected for the relief was transformed into a residual anomaly curve and a variation curve.

The residual anomaly (Δg) is noted within the range of PK 20-37, i.e. it has a profile width of 170 m. Its maximum value on PC 26 reaches 1.66 mGal. Such a large anomaly in size and intensity can only be caused by a large body with a significant excess density. Comparison of the data of gravimetric observations with the geological section constructed according to this profile, based on the sinking of the tunnel 11, dissections and underground drilling, indicate that the anomaly is caused by irregularly shaped ore bodies placed among the rocks (Fig. 2).

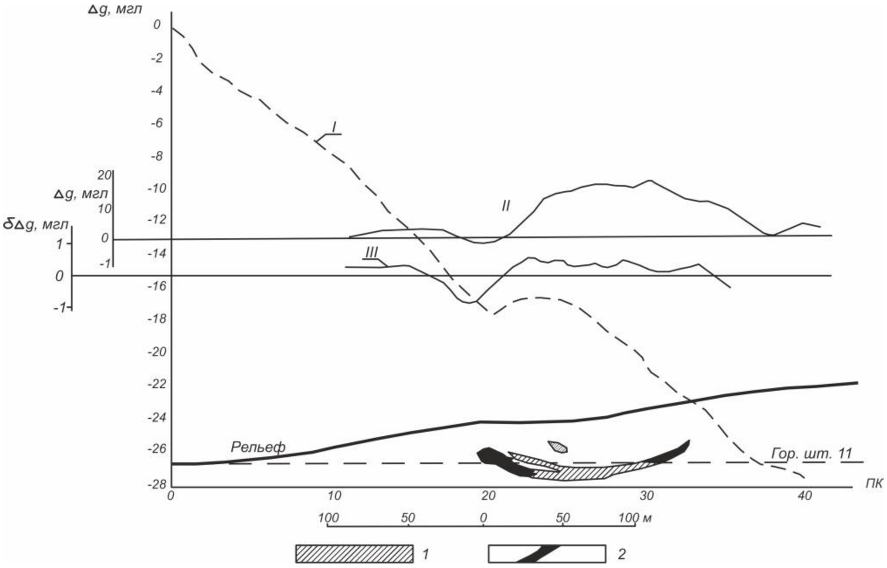

Fig. 2. Curves of gravity anomalies (Vostochny Kantash).
Profile on the surface above the tunnel 11.
I – the observed curve (Δg); II – the curve of the residual anomaly; III- variation curves (δ Δg) of gravity changes; 1 – skarns; 2 - polymetallic ores.

The ore body lies at the level of the horizon of the tunnel 11 and dissects it in such a way that one part of it is above the horizon of the tunnel, the other is higher (Fig.2). According to the calculation, the depth of the center of gravity (hc) is 30-35 m. The absence of separated anomalies on the curve (Fig. 2) indicates that the anomaly-forming object is represented by a single body. The relatively shallow placement (hc) of the body from the daytime surface, marked by gravimetric data, indicates that between the daytime surface and the horizon of the tunnel 11, within the limits of PK 20-37, separate, possibly separated bodies of skarns, similar to the body marked on PK 26-27, can be placed among limestones.

On the profile passed along the trunk of the tunnel 11 (horizon 1734), there is a decrease in the observed value of gravity throughout its entire length from PC 0 to PC 40.

The residual curve shows negative anomalies within PK 25 -28, it is caused by the influence of excess masses located above the horizon of the tunnel, this anomaly reflects the two skarn zones that are allocated within PK 25-28 and placed among limestones in contact with granodiorites above the horizon of the tunnel.

Within this interval, the variation curve also experiences decreasing changes, i.e. it acquires negative values, which confirms the stated position about the influence of ore bodies. On the observed curve Δg (Fig.3), the curves of the residual anomaly and the variational one, the influence of ore bodies intersected by the tunnel

does not actually affect. This gives reason to believe that the tunnel 11 intersects ore bodies, so that the mass of the body located above the horizon of the tunnel is compensated by the mass of the body located below this horizon.

A small ore zone with polymetallic ores, which have a high density exceeding 4.5 g/cm3 (8.5 pc), and skarns with a relatively low density on PCs 11-12, are crossed by the shaft 3 of the tunnel 11 (horizon 1734) on PC 5. On PC 16.5-17, the skarn zone has a maximum density not exceeding 3.5 g/cm3

On the observed curve Δg, these zones did not receive a sufficiently clear reflection. Positive anomalies are observed on the transformed curves (residual and variational in the intervals of 20-50 and 80-110 m) [9,10]. The nature of these curves, the change of positive anomalies, negative ones of the same width, indicates that at these intervals there are two ore bodies with falls other than vertical, while the upper end of the body, placed above the level of the drift, creates a negative anomaly, and the lower one – a positive one.

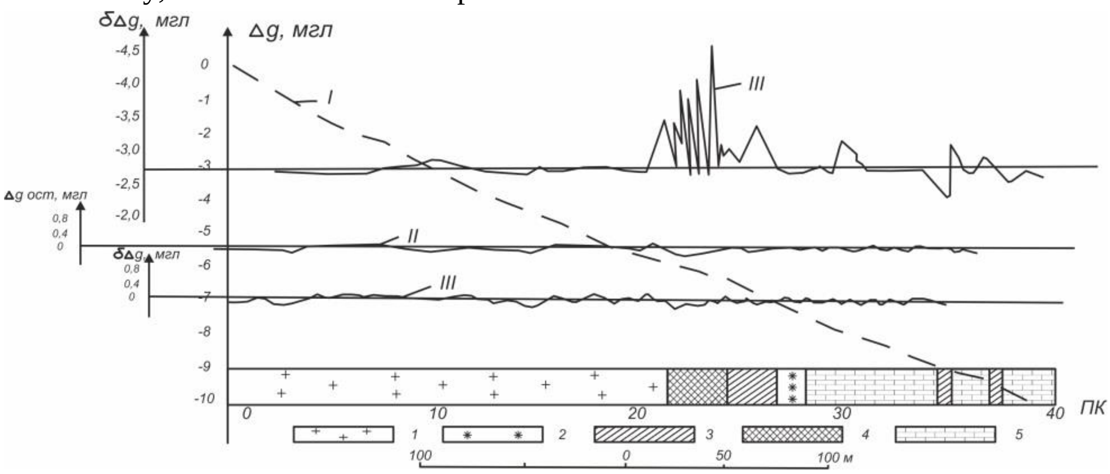

Fig.3. Curves of gravity anomalies (Vostochny Kantash).
Profile on the surface above the tunnel 11.
I – the observed curve (Δg); II – the curve of the residual anomaly; III- the variation curves (δΔg) of gravity changes;
1–diorites; 2-granodiorites; 3–skarns; 4–ore; 5- limestones.

The following example applies to the Kurusai site. The site is located in the middle part of the Kurusai Ridge in the area of the connection of Tutlin and Effusive fractures and is timed to coincide with the contact of tourney marbles with Quartz porphyries of the oyasai formation.

Skarns Turangles have a zonal structure, pyroxene differences of skarns are confined to the external one, and Garnet differences to the internal halo of the zone. Skarns are magnetite and polymetallic. Magnetite arming is developed in garnet skarns placed on the contact of marbles with diorites and granosienites.

Polymetallic activity is associated with pyroxene skarns developed in contact with quartz porphyry. A special feature of this polymetallic site is that the surface of the ore-controlling contact forms a concave cup-shaped structure. Its complexity and the presence of multiple bends of the steep south-east slope are noted. Enriched areas are timed to coincide mainly to concave areas of the contact surface (Tarasov, 1967).

Gravimetric measurements were made in adit 4, 4A (horizon 645.4 m), adit 7 (Horizon 600.1 M) and adit 6 (horizon 567 m) (fig.4).

In Tunnel 4, the profile crosses the ore zone from picket 10 to picket 25. From PK 0 to PK 10, the profile has a direction from northeast to southwest and is straight from pickets 10 to 50. The observed curve Δg decreases sharply to PK 10 (Fig.5). The negative value of Δg in the area of the entrance to the ore body is 6 mGal relative to the value at PK 0. The nature of the anomalous field is due to the presence of polymetallic ore bodies among the rocks opened by the tunnel during pickets 13 and 23 with the main ore mass located below the horizon of 645.4 m.

4. Discussion

The presence of the main ore mass is confirmed by a residual anomaly, quite clearly marked at pickets 17-27 and having a maximum value of δΔg at picket 22 equal to 0.86 mGal. The variation curve δΔg also confirms the presence of a disturbing body in this interval. The amplitude of the anomaly of the variation curve is 0.48 mGal.

The nature of the field of the observed curve Δg, the placement of the maxima of the residual and variation curves along the horizon profile 645.4 indicate that the ore zones and scarns developed at the contact of marbles with diorites have a steep north-easterly drop.

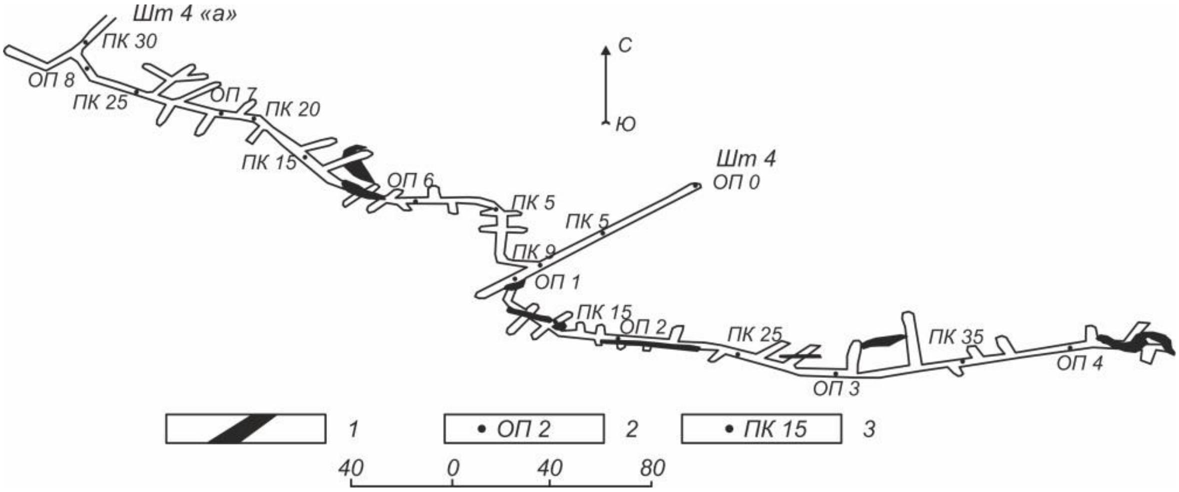

Fig. 4. Kurusai deposit (Turangly site).
Plan of tunnel 4a with observation points.
1 – polymetallic ores 2-reference points of gravimetric measurements; 3 – observation points of the ordinary network.

The nature of the distribution of Δg along the profile in the tunnel 4a (horizon 645.4) is shown in Fig.5. The sharp decline of the observed curve Δg to PK 20 is complicated by quartz diorites at pickets 1-20 (PK 14-15). Their influence is so significant that a maximum of 036 mGal is allocated in the residual anomaly, confirmed by a variational anomaly with a relatively high amplitude of the gravity value Δg, which is explained by the influence of ore bodies and quartz diorites intersected by a tunnel. On the residual anomaly Δg, three anomalous zones with an intensity from 0.17 to 0.2 mGal are distinguished along the profile. Starting from PC 25, there is a general steep rise in the observed curve Δg.

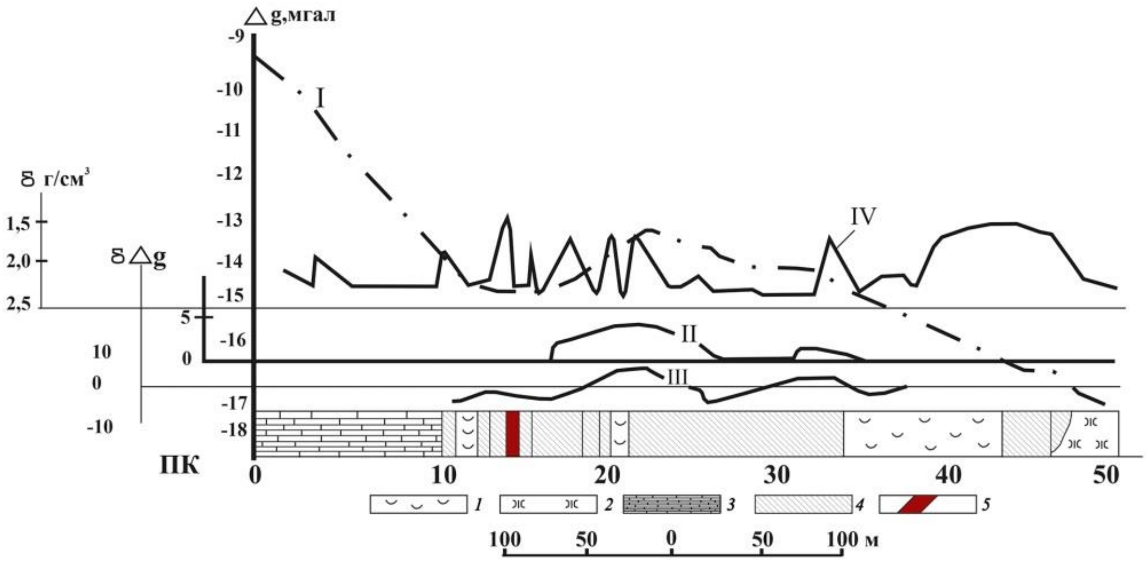

Fig. 5. Curves of gravity anomalies (Kurusai, tunnel 4, horizon 645.4 m.).
I – the observed curve (Δg); II – the curve of the residual anomaly; III- variation curves (δΔg) of gravity changes; 1Y – the curve of rock density along the measurement horizon; 1–diorites; 2-granodiorites; 3–limestones; 4–skarns; 5- polymetallic ores.

Positive anomalies on the residual curve indicate the placement of ore zones below the horizon of the tunnel 4a. According to the data of electrical exploration work carried out in wells 4a, 7 and 6, the correlation of ore bodies on PC 20-23 is confidently noted. adits 4a with ore bodies on PC 24-25 adits 7 and even with ore bodies on a deeper horizon in adit 6 (picket 67). And therefore, the calculated excess masses of bodies performed by various methods [4,5] actually reflect the masses of ore bodies below the horizon of the adit 4a and are additional to the compensated masses placed above and below the horizon of the adit 4a.

On the profile passed in tunnel 7 (horizon 600.1m), a decrease in gravity in the direction from the mouth (PC) to the bottom (PC 70) with characteristic changes was revealed, due to the influence of the underlying excess masses. The changes noted on the observed curve Δg clearly enough (after the introduction of the correction for the relief and removal of the background) manifested themselves on the curve of the residual anomaly in the form of four anomalies noted within pickets 4-12 with a maximum positive anomaly value of 0.68 mGal, pickets 13-25 (0.42 mGal), pickets 26-38 (0.26 mGal), pickets 33-57 (1.46 mGal).

5. Conclusion

1. Conducting gravimetric underground investigations along the horizons is also accompanied by ground-based gravity observations, which makes it possible to detect ore bodies between the earth's surface and mining, as well as between horizons.

2. The data of underground gravimetric observations are considered within the framework of a three-dimensional model in order to identify mineralization around the mine workings.

3. The study of the gravitational field on the upper horizons of the Kurusai and Kantash deposits showed that the localization of mineralization is observed between the earth's surface and the upper horizon, while a sharp weakening of gravitational anomalies is observed on the lower horizons.

4. The presence of underlying mineralization relative to the deep horizon is marked by noticeable positive anomalies of the gravitational field, whereas anomalies from disconnected mineralization both above and below the horizon are characterized by minor changes in the gravitational field.

Thus, the use of underground gravity exploration will allow us to study not only the morphology of ore objects, but also their presence around mine workings. In general, this information is used to uncover new ore objects by laying additional mine workings.

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