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Research Article

CHARACTERISTICS OF GOLD MINERALIZATION DISTRIBUTION DETERMINING THE METHODOLOGY AND RELIABILITY OF EXPLORATION AND RESERVE ESTIMATION AT THE KAULDY DEPOSIT

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ABSTRACT
The article presents the characteristics of gold mineralization distribution that determine the methodology and reliability of exploration, the nature of gold distribution, the main ore-controlling and ore-bearing structures, and the internal structure of ore bodies in the Kauldy deposit. To assess the reliability of reserve calculations for the Kauldy deposit, a comparison is provided between the results obtained using the traditional method and those based on a geostatistical method using a block model.

Keywords: *Non-confirmation, reserves, reliability, unevenness, block modeling, ore-bearing zone, estimation blocks, ore bodies.*

INTRODUCTION
Currently, developed countries are conducting extensive research to develop scientifically grounded methods for geological exploration and assessment of gold ore deposits. In this process, licensed software packages are utilized to re-evaluate reserves based on new technically and economically justified exploration parameters. All of these efforts contribute to increasing the efficiency of geological exploration and expanding the country's mineral resource base.

In global practice, the detailed study of factors that determine the features of geological structures in gold ore deposits, as well as methodologies for their exploration and reserve estimation, remains relevant, along with geological and economic assessment. Particular attention is paid to the comprehensive processing of existing geological, mining, and technological materials, along with the application of modern methods for their analysis and interpretation of the obtained results.

Currently, our country extracts ore, non-ore, and combustible minerals, which are found in the earth's crust in solid, liquid, or gaseous states. The methodological approaches for their exploration, sampling, delineation, and geological-economic assessment are highly diverse. These approaches depend on the characteristics of the geological structure of ore fields and deposits, the composition of the minerals, the specific features of their composition, as well as the conditions for their development, processing, and industrial utilization.

The study of ore composition enables the selection of the most efficient enrichment methods and ensures comprehensive processing and utilization of mineral resources. (Isokov M, Zimalina V, Koloskov S., 2013).

However, at the deposits, factors affecting the reliability of exploration and reserve estimation have not been fully studied. Moreover, the digital age has necessitated the use of modern software complexes by international standards. Addressing this issue will allow for a more effective and accurate determination of the methodology and reliability of reserve estimation, as well as the possibilities for expanding the mineral resource base of gold-bearing and flux ores.

MATERIALS AND METHODS

The Kauldy deposit is located in the Kauldy ore field within the Akhangaran district of the Tashkent region. It is situated on the northern slopes of the Kurama Range in the middle reaches of the Almalyk, Kauldy, and Kyzata Rivers, which are left tributaries of the Angren River (Mirkamalov R., 2010).

The deposit was discovered in 1960 during exploration and revision work. It was intermittently studied under the name Kauldy until 1967 when hidden ore bodies were found and its industrial significance was proven. From 1968 to 1972, a preliminary and detailed exploration of the deposit was conducted. Sixteen ore-bearing zones were identified, conventionally divided into three areas: Northern, Central, and Southern (1969-72).

The deposit is located in the Central tectonic block of the Almalyk ore district, bounded to the north by the Burgundy fault and to the south by the Miskan fault, both of which are first-order faults. These faults are accompanied by numerous systems of branching minor faults and fractures (Golovanov I., 2001).

Among the fault disruptions recorded in the area of the district, the following are distinguished by scale: first-order faults (Karabulak, Burgundy, Miskan, Bashtavak), which can be traced throughout the entire area of the district; second-order faults, extending for 10-20 km; and higher-order disruptions: small faults and fractures.

The main valuable component of the ores is gold, with silver as a secondary component. The deposit is predominantly characterized by fine-grained and hornfels ore structures, while the textures are mainly banded and massive, with disseminated and stockwork-disseminated textures occurring less frequently.

The deposit is composed of volcanogenic rocks of the andesite-dacite formation (C_2-C_3), divided into the Akchin, Nadak, and Bolgaly suites, which are underlain by a carbonate sequence (D_2-C_1) at a depth of 200-500 m from the surface.

The main ore-controlling and ore-bearing structure of the deposit is the Main Flat Zone. The ore bodies of all three areas are confined to a single ore-controlling structure - the Main Ore-Bearing Zone. They have similar sizes, ranging from 60-100 to 200-380 meters in diameter.

The ore bodies of the Kauldy deposit, primarily associated with quartz, quartz-hydromica, and quartz-carbonate metasomatic rocks, are characterized by an uneven distribution of gold.

At the deposit, quartz-hydromica metasomatites are manifested mainly in clastolavas of andesitic composition. Quartz-hydromica metasomatites are characterized by linear orientation and quite distinct vertical and horizontal zonation.

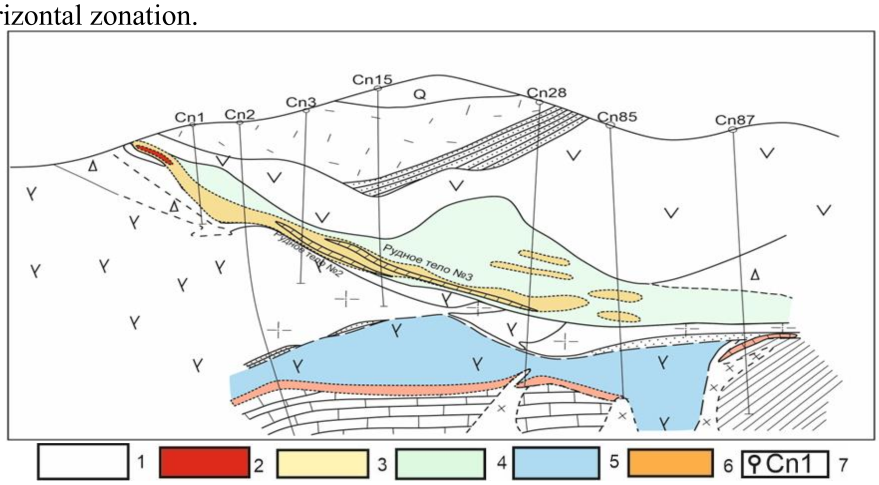

Figure 1. Distribution of metasomatites along the cross-section (based on materials by E.Z. Meshchaninov, 1972). 1 - propylites; 2 - monoquartz; 3 - quartz-hydromica; 4 - carbonate-chlorite-hydromica; 5 - silicified, sericitized, and epidotized rocks; 6 - silicified and skarnified limestones; 7 - boreholes for which detailed petrographic cross-sections were compiled.

Morphologically, the ore bodies are represented by sheet-like and lens-shaped deposits, predominantly gently dipping, with angles of inclination up to 10-35°. Their extent along strike and dip reaches several hundred meters, while their thickness can be up to several tens of meters with swells and pinches. The boundaries of the ore bodies are indistinct and are established based on sampling data. When correlating the ore bodies, the elements of occurrence, compositional features of metasomatites, and endogenous geochemical halos were taken into account.
Figure 2 shows the geological cross-section along line 14-14 and depicts the placement of ore bodies within the intraformational zone (ore bodies No. 2, 3) at the stage of detailed assessment of the Central area. The largest ore body has the shape of an irregular lens-like deposit, sometimes splitting at the flanks, with dimensions of 450m along the strike and 200m along the dip. It is located in the Main Flat Zone between elevations 930m and 860m. The ore body dips 10-40° to the east; in some intervals, it flattens out and has an almost horizontal occurrence (Rakhmonova N, Okhunov A., 2023).

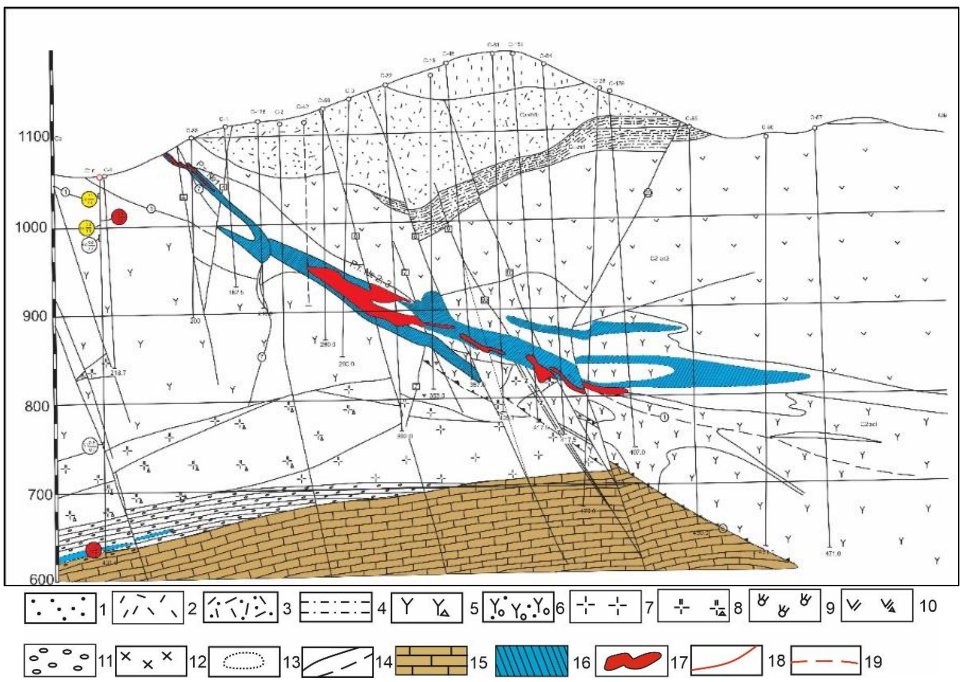

Figure 2. Examples of ore body placement in different structural-stratigraphic positions. Ore bodies in intraformational position (geological cross-section along lines 14-14 of the Central area, ore body No.2-3). 1 - sandstones; 2 - crystalloclastic lavas, tuff lavas, clastic lavas, and tuffs of dacite-porphyries; 3 - tuffaceous sandstones; 4 - siltstones and sandstones; 5 - andesitic porphyrites; 6 - limestone and polymictic conglomerates, gravesites, sandstones, siltstones, and suffices (basal layer); 7 - subvolcanic biotite granodiorite-porphyries and andesite-dacite porphyrites; 8 - granodiorite-porphyries of Kalkan-ata; 9 - subvolcanic biotite andesite-dacite porphyrites; 10 - tuffs, tuff breccias, lava breccias of biotite andesite-dacite porphyrites; 11 - conglomerates; 12 - syenite-diorites; 13 - skarnification; 14 - rock contacts: traced (a) and inferred (b); 15 - carbonate deposits (limestones); 16 - hydromicaceous-quartz metasomatites; 17 - ore body contours; 18 - steeply dipping faults; 19 - gently dipping zones (faults).

The mineral composition of most ore bodies is fairly uniform and consists of quartz, often with a breccia-like texture, quartz-hydromica metasomatites with finely dispersed high-grade native gold, and a minor proportion of sulfides.

RESULTS AND DISCUSSION

Gold mineralization in the Kauldy deposit is primarily localized within zones of quartz-hydromica metasomatites. The presence of extensive zones of quartz-hydromica metasomatites serves as a direct prospecting indicator for the discovery of gold ore bodies.

Thus, ore-bearing and mineralized zones, as well as ore-hosting rocks, were studied using a complex of mineralogical-petrographic and chemical-analytical research methods. The chemical composition of ores and ore-hosting rocks was examined through complete silicate analysis. The contents of the main and associated components were determined using spectral semi-quantitative, ICP-mass spectrometric, and atomic absorption research methods. Within the Southern I area, the following types of ore-hosting rocks have been identified: andesite (meta-andesite), andesidacitic porphyrite, dacite porphyry, andesibasalts, andesitic lava breccia, and limestones. All rocks exhibit varying degrees of metasomatic alteration (Figure 3).

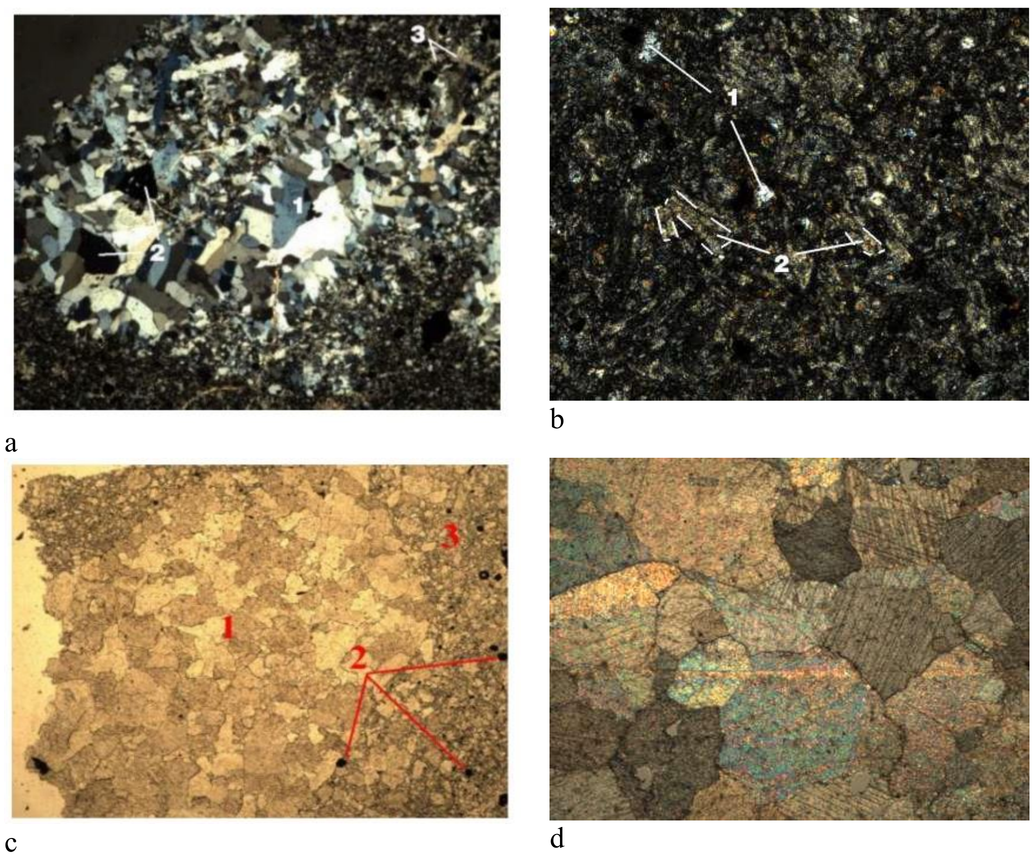

Figure 3. a) Nest-like quartz accumulation in andesite - thin section Southern-1, magnification 40x, crossed Nicols. 1 - quartz; 2 - ore mineralization; 3 - carbonate; b) Andesitic-dacitic porphyrite - thin area Southern-3, magnification 40x, crossed nicols. 1 - white - quartz; 2 - brownish-sericitized, chloritized, and pelitized feldspars; c) Carbonatized dacite porphyry - thin area Southern-3, magnification 40x, crossed nicols. 1 - white - quartz; 2 - brownish-serialized, chloridized, and pelletized feldspars; d) Carbonate rocks (limestone) - Thin area Southern-11. Magnification 40x crossed Nicols. Grayish-brown with traces of cleavage - carbonate, black - sulfides. Left. 40x, Nick.

The mineralization is located within argillized rocks, which exhibit a distinct zonation relative to the core body composed predominantly of quartz or quartz-calcite.

Mineral composition of ores from the South-1 area

Extent of prevalence	Non-metallic (rock-forming)	Ore minerals
widespread	plagioclase, sericite, volcanic glass, epidot, chlorite, carbonate, quartz	pyrite, magnetite, chalcopyrite, hematite, native gold
Sparsely distributed	clay minerals, potassium feldspar, barite	antimonite, sphalerite, galena, tetrahedrite, covellite, chalcocite, goethite, limonite, native silver, hessite, krennerite, pyrrhotite
Rarely distributed	apatite, monazite, zircon, zoisite	ilmenite, rutile, aurostibite, leucoxene

The gold-sulfide-quartz type includes deposits (Zimalina V, Isoqov M, Koloskova S., 2008) characterized by the presence of sulfides (pyrite, chalcopyrite, fahlore, galena, sphalerite) and other ore minerals (native gold).

Gold in ores occurs both as free gold in quartz and is associated with sulfides, tellurides, and sulfosalts. In hydrothermal ores, gold is found in native, visible form, as mineral compounds with other elements (mainly tellurides), and as finely dispersed, scattered inclusions in sulfides (pyrite, chalcopyrite, arsenopyrite, etc.). Native gold is primarily present in intergrowths with pyrite.

A characteristic feature of mineral deposits is the spatial variability of mineralization parameters and other studied properties (thickness, content, ore saturation, ore body area, occurrence elements, ore texture and structure, etc.), which is determined by geological and genetic conditions under the influence and interaction of numerous factors.

The coefficient of variation (of content, thickness, or metrograms) can be used as an indicator of gold mineralization variability. From this perspective, S.A. Denisov provides a classification system for deposits.

As is well known, gold deposits belonging to groups III and IV of exploration complexity are characterized by an extremely uneven distribution of gold within the ore bodies. (Zimalina V, Khamroev I *et al.,* 2019, Zimalina V, Gleyzer L., 2022). Based on a detailed assessment, the Central and Southern areas of the Kauldy deposit have been classified as belonging to the 3rd group of geological structural complexity. To determine the geological complexity group more accurately, a comprehensive statistical analysis was conducted for the Southern II area to calculate the coefficients of variation in ore intersection thickness and gold content. The variation coefficients were determined using corresponding histograms generated by the Micromine software package, considering cut-off gold grades of 1.5, 1.0, and 0.5 g/t (Fig. 4).

As evident from the histograms, the coefficient of variation for the thickness of ore intersections at gold cut-off grades of 0.5, 1.0, and 1.5 g/t is less than 100% (82.3%, 82.6%, and 97.2%, respectively). The coefficient of variation for gold intersections is more irregular, comprising 191.6% at a cut-off grade of 1.5 g/t, 234.2% at 1.0 g/t, and 299.3% at 0.5 g/t. According to this indicator, the Southern-II area belongs to the 4th complexity group (coefficient of variation greater than 150%) (Figure 5). Analysis of the results shows that the coefficient of variation for gold intersections is most irregular at the cut-off grade of 0.5 g/t.

Within almost every deposit (ore field), it is possible to identify an ore-bearing horizon or zone where the main mass of ore bodies is concentrated. Based on studies of numerous hydrothermal deposits (mercury, antimony, polymetallic, bismuth, gold ore, and others), researchers have determined that the reasons for unconfirmed reserves are geological, methodological, and technical factors. One of the primary geological factors is the morphology of ore bodies, the degree of uneven distribution of ore bodies within the ore-controlling structure, and the distribution of valuable components within them - in other words, the internal structure of the ore body.

The primary factor determining the required density of the exploration grid is the degree and nature of the deposit's variability. An analysis of methodological factors affecting exploration reliability was conducted to identify the optimal density of the exploration grid and to obtain the most accurate assessment of

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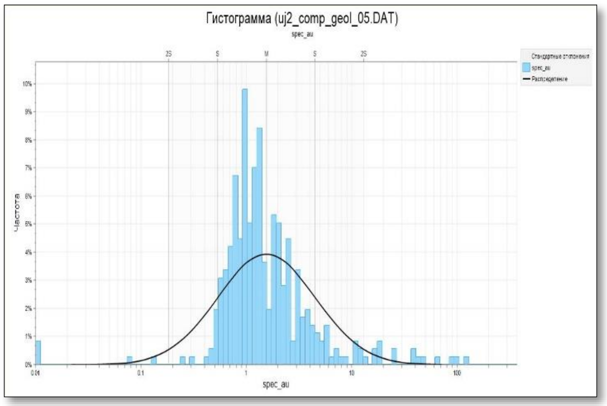
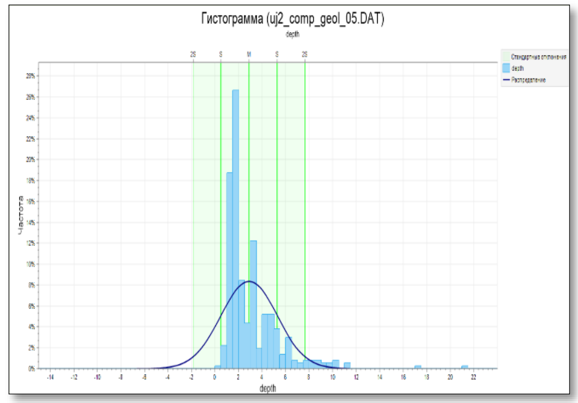
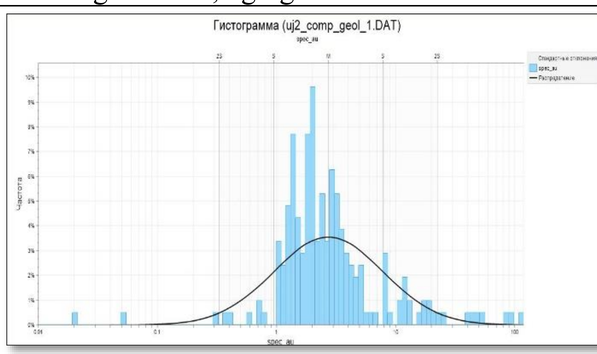
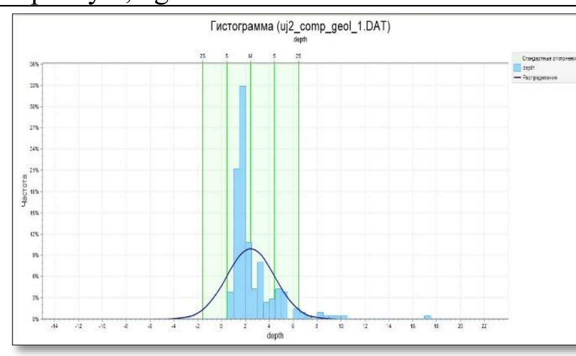
calculation parameters and reserves. For the drilling exploration of gently sloping ore bodies, a sample detailing section from block I-C_1-22 of ore body No. 22 was selected. By reducing the grid density to every other section, two options for outlining the block were obtained (Figure 6).

	
Cut-off grade of 0,5 g/t gold	capacity 0,5 g/t
	
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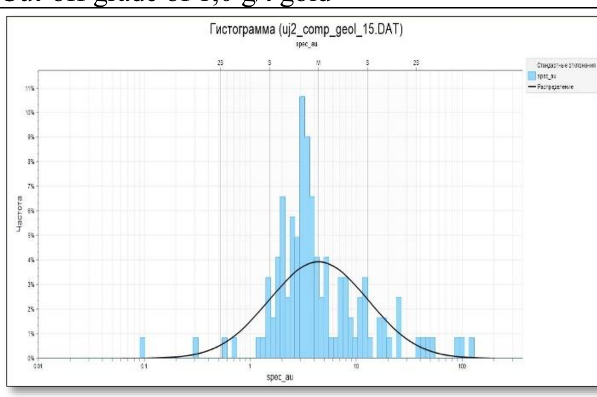
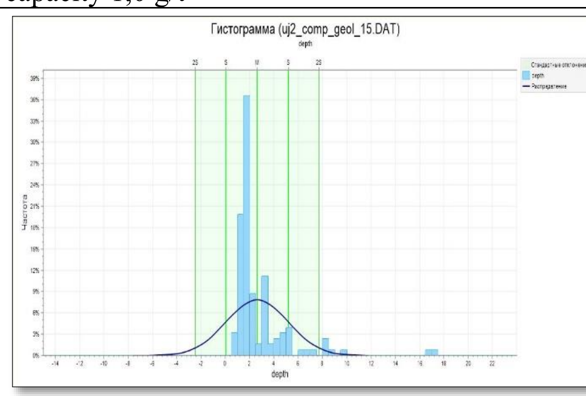
	
Cut-off grade of 1,5 g/t gold	capacity 1,5 g/t

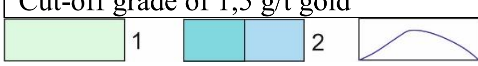


Figure 4. Histograms showing the distribution of thicknesses and gold contents for composites within all ore bodies at cut-off grades of 0.5, 1.0, and 1.5 g/t in the Southern II area. 1 - standard deviations; 2 - length; 3 - distribution.

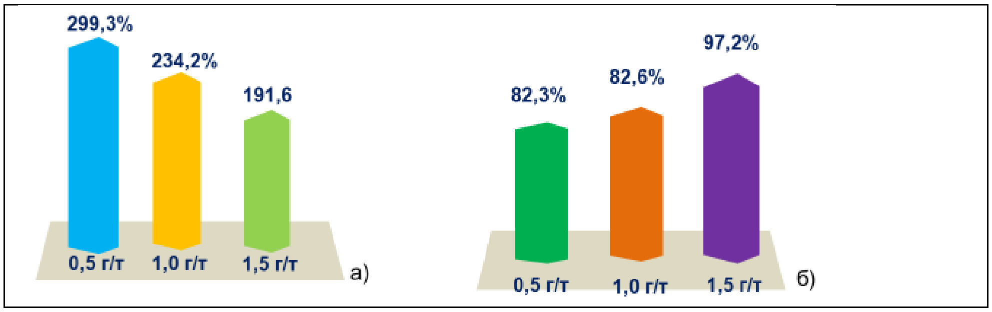


Figure 5. General statistical analysis of the Southern II area. Distribution of variation coefficients for gold content (a) and thickness (b) across all ore bodies (cut-off grade options: 0.5, 1.0, 1.5 g/t).

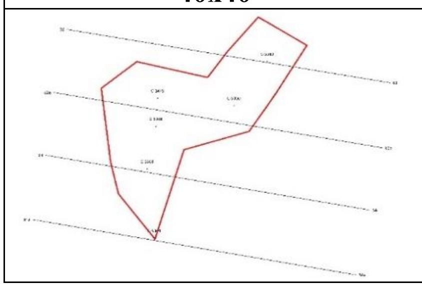
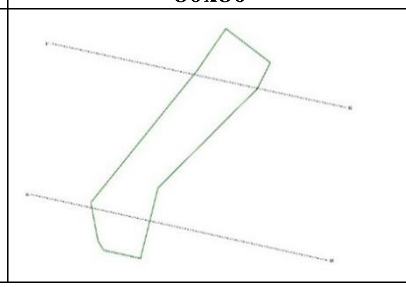
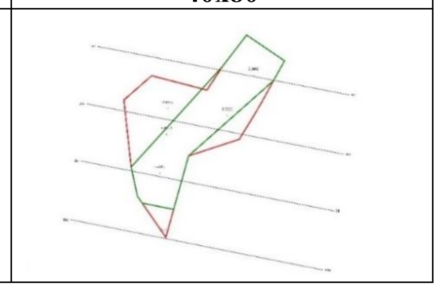
40x40	80x80	40x80
		

Figure 6. Changes in the contours of calculation block No.18-2-1-S1 when the 40x40m exploration grid is expanded to 80x80m in the Southern I area. 1 - block contour with a 40x40m exploration grid; 2 - block contour when the grid is expanded to 80x80m; 3 - a volumetric model of the block with an 80x40m exploration grid.

Separation was carried out between profiles along the 40x40m to 80x80m exploration network. As can be seen from the figures, the morphology of the ore body in the block changes significantly with a small number of mine workings. This is explained by the complexity of the gold mineralization distribution morphology within ore bodies, which affects the reliability of reserve calculations. Determining the reliability of the calculated parameters and reserves at the accepted network density at the deposit by comparing them with the parameters calculated during rarefaction showed that the block area decreases by -7.14%, the capacity by -16.3%, which leads to a decrease in ore reserves by -22.3%. The average gold content was 3.2 u.s. at the 40x40m exploration network, and the network thinning to 80x80m, leading to a 12.5% increase. The decrease in gold reserves was 12.5%. When the network was rarefied, the most variable parameters were identified - area, power, and average gold content.

Based on the results of a detailed assessment, the reserve estimation was conducted using the geological block method, which was determined by the structural features, ore body occurrence conditions, and exploration methodology (Smirnov A, Prokofiev *et al.,* 1960). The construction of the calculation blocks was performed on the projection of ore bodies onto the horizontal plane.

The classification of reserves and forecast resources of solid minerals establishes unified principles for the Republic of Uzbekistan for categorizing reserves and forecast resources of solid minerals based on the degree of their exploration and economic significance. According to new international requirements, the traditional method is now used as a control method. In light of this, reserves at the Kauldy deposit have been recalculated using the geostatistical method based on a block model using Micromine software (Fig.7). The reserve recalculation was performed by updated regulatory and methodological documents adapted to international requirements (Okhunov A, *et al.,* 2022). For the joint development of the Central and Southern areas, a cut-off grade of 1.0 g/t gold is accepted as optimal for reserve calculation, ensuring the most complete extraction of gold-bearing ores from the subsurface while maintaining satisfactory economic indicators. As a result of the recalculation, ore reserves in the C_1+C_2 categories at a cut-off grade of 1.0 g/t gold increased by 103.5% compared to the previously accepted cut-off grade of 2.0 g/t, while gold reserves increased by 22.9% across the three areas: Central, Southern, and Southern II.

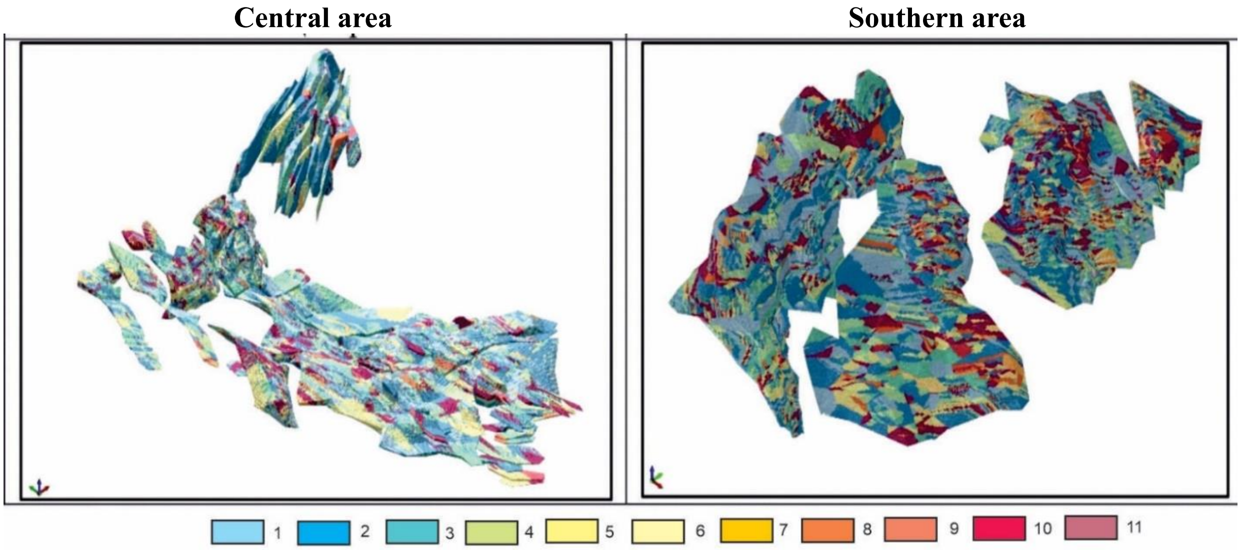


Figure 7. Distribution of gold reserves across ore bodies in the block model. 1 - <0.5; 2 - 0.5 to 1.0; 3 - 1.0 to 1.5; 4 - 1.5 to 2.0; 5 - 2.0 to 2.5; 6 - 2.5 to 3.0; 7 - 3.0 to 3.5; 8 - 3.5 to 4.0; 9 - 4.0 to 4.5; 10 - 4.5 to 5.0; 11 - >5.0.

The calculation of reserves using the block model was compared with the results of the traditional method of geological blocks on vertical and horizontal projections of ore bodies, using the Southern I area as an example. The results show that, overall, the discrepancies for the section are within acceptable limits (±10% for thickness, ±5% for metal content, ±15% for reserves). The main reason for the discrepancy in gold reserves and their average content between the block model calculation and the traditional method is the extremely uneven distribution of metal and the presence of anomalous cross-sections in terms of thickness or content.

CONCLUSION

1. At the Kauldy deposit, gold mineralization is primarily associated with a geological structure complicated by fault displacements of various orders.
2. The most favorable zones for the localization of ore bodies are areas with developed quartz-hydromica and carbonate-hydromica metasomatites associated with gently dipping (10-35°) structures. The presence of extensive zones of quartz-hydromica metasomatites serves as a direct prospecting indicator for the discovery of gold ore bodies.
3. Statistical analysis has shown that the studied Southern II gold ore area exhibits a high degree of uneven gold distribution and belongs to the IV complexity group based on variation coefficients exceeding 150%.
4. When thinning the network, the most variable parameters were identified: area, thickness, and average gold content.
5. The reserves of the Kauldy deposit have been recalculated by the requirements of regulatory and methodological documents updated to meet international standards The recalculation of gold reserves using

new parameters, with a sequential reduction in the cut-off grade from 2.0 g/t to 1.5, 1.0, and 0.5 g/t, resulted in a 22.9% increase in the deposit's recoverable gold reserves, with the optimal variant being 1.0 g/t.
6. The results of comparing traditional and block (PC Micromine) methods for reserve estimation show an acceptable discrepancy in gold reserve assessment, which does not exceed ±5.8%.
7. Based on the statistical analysis of the Kauldy deposit and considering the 4th group of the complexity of its geological structure, it is recommended to combine the exploration of these areas with advanced operational exploration.

REFERENCES
Golovanov (2001). Ore deposits of Uzbekistan (Tashkent, GIDROINGEO).
Isokov M, Zimalina V, Koloskov S (2013). Conditions for the placement of gold mineralization, methodology, and reliability of exploration on the example of the Gujumsay deposit (Tashkent), p.185
Mirkamalov R. (2010) Atlas of models of ore deposits of Uzbekistan (Tashkent), p.99.
Okhunov A. et al. (2022). Methodological Guidelines on the Content, Formatting, and Procedure for Submitting Materials on the TEO of Conditions and Calculation of Reserves for Solid Minerals Using Block Modeling (Tashkent).
Rakhmonova N, Okhunov A. (2023). Structural-stratigraphic factors determining the exploration methodology at the Kauldy gold deposit (Tashkent), p.64-68. Bulletin of the University of Geological Sciences.
Smirnov A, Prokofiev *et al.,* (1960). Calculation of reserves of mineral deposits (Moscow), p. 671.
Zimalina V, Gleyzer L. (2022). Instructions for the application of the classification of reserves to gold deposits (Tashkent).
Zimalina V, Khamroev I *et al.,* (2019). Peculiarities of the geological structure, reliability of exploration and calculation of the reserves of the Charmitan gold deposit. Ores and Metals(**4**), p. 4-10.
Zimalina V., Isoqov M.., Koloskova S. (2008). Geological-industrial types, assessment and exploration of gold ore deposits of Uzbekistan (Tashkent), p.255.