Problems of geometrization, delineation and reserve estimate of gold fields

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Abstract. The paper presents the experimental data on ore gold distribution in a field, which is characterized by highly uneven mineralization up to nesting, presence of coarse gold and lack of clear rock control. It considers the main problems of exploration and assessment of similar fields, provides and justifies solutions making it possible to avoid or reduce interpretation errors of exploration and sampling, to increase the delineation reliability of ore bodies.

1. Introduction
Geometrization of mineral deposits is understood as the “…set of observations, measurements, computing and schematic efforts aimed to obtain the geometry of forms, properties of mineral resources, mode of occurrence and subsoil processes” [1]. In other words, it implies the identification of field structure regularities, distribution of valuable and harmful elements, geomechanics of a rock massif within subsoil assets.

It is difficult to overestimate the importance of this stage of field study. If the given features are not reflected in due time in plans, sections, digital models of a field and ore bodies, then both small and large errors in reserve estimate, and hence, in design and construction of any mining plant, as well as problems related to further field development may be fairly solved.

The specific gravity of gold fields has been increasing from the second half of the 20th century when placer gold reserves were considerably reduced thus causing the subject-matter search for primary deposits despite the skeptical opinion that all hard-rock gold reserves are processed by nature into placer gold. In this regard, the study of the geologist A.I. Ivanov, who demonstrated the presence of primary gold deposits in the territory of the Lensky gold field [2, 3] and discovered a new type of primary fields in the Bodaybo ore district [4], seems quite relevant. These fields, as well as gold ore fields of other regions [5-7] are usually characterized by extremely uneven distribution of a valuable element, quite often nesting, complex morphology, and hence, according to their geology they most often belong to the III-IV group of complexity. Therefore, they are difficult to geometrize using known analytical and graphic methods, which leads to manual and subjective methods of resource delineation and reserves estimate. These fields are characterized by irregularity, nesting distribution of a valuable element, high asymmetry and kurtosis. At the same time, many mathematical methods applied in geometrization (polynomial functions,
correlation, auto-correlation, trend analyses, etc.) utilize the least square method based on the normal distribution law. This leads to the conclusion that the above methods are not sufficient and fail to solve the main task of geometrization, i.e. to reveal the existing trends and regularities.

The applied geographic information systems provide for reserves estimate with certain degree of reliability only after delineation of ore bodies, zones, and deposits. The industrial experimental studies of one field showed that under high contrast of ore grade mineralization the error of field limits definition (top or bottom) reaches 4-10 meters depending on the cut-off grade, which dramatically reduces the efficiency of the most advanced methods of reserves estimate.

What are the features of gold distribution within such fields and what are the consequences? Let us give the main short but not complete list of those features [2-5, 8-11].

The first is the discretization of gold particles reaching the nesting distribution. The second includes high asymmetry and kurtosis of gold concentration resulting from discretization. The third is the noncompliance of sample geometry in a well with the geometry of gold particles distribution in situ.

The fourth is the noncompliance of sample volume (too small) with gold particle size distribution in a field.

The fifth is the difference of gold distribution from standard distribution, which to a considerable degree prevents the application of mathematical methods.

The sixth is the distance between exploration works often exceeding the affected area of a sample thus resulting in contouring ambiguity of ore bodies between wells.

The above features of gold mineralization lead at geometrization, reserves estimate, feasibility study and cost analysis with regard to some problems listed below:

1. Development of the evidence base of reliability of exploration and sampling data.
2. Correct definition and accounting of hurricane samples (abnormally high) in small samples leading to overestimated reserves in certain blocks and cross-sections, as well as to limited possibility of utilizing the mathematical model.
3. Accurate definition of top and bottom of a deposit, an ore body or a mineralization zone in vertical section.
4. Integration of ore bodies in vertical section and between cross-sections without clearly defined lithologic, stratigraphic and other types of geological control over mineralization.

The purpose of the given work is to solve some of the above problems using the example of a small Ozherelie gold field (less than 10 t of gold).

2. Materials and methods
Experimental works within a study object with further statistical and geo-information analysis of the obtained data.

Concerning the main issue of reliability and accuracy of data obtained by the expert organization LLC Oreol under the contract with JSC Vysochayshy the study covered a unique experiment on a chosen site. Forty well pads, from which 28 represented close-paired wells with a drill bit diameter of 96 mm and 131 mm, were drilled here. Another 12 well pads included 5 wells drilled via the X-shaped sampling method: the central well was drilled with a drill string having a drill bit diameter of 131 mm, and 4 corner wells – with a 96 mm drill bit. The distances between wells in a pad did not exceed 1.5 m. All wells were tested in segments with a course length of approximately 1 m. The horizontal drill sites were constructed to ensure identical hypsometric level of samples and their further comparison.

23 out of 40 well pads were drilled with inclination wells, and the others – with vertical ones. The common disadvantage of these works is that some pads failed to fully cross the mineralized thickness.
Despite this fact, the obtained data served a good statistical material to study the features of a zone structure in vertical and to solve the issue of drilling data status in the field, and to account hurricane samples and to set the adjustment coefficient to the mineral content. Deep holes of 20 m in depth and with a section of 4 m\(^2\) were made to confirm the drilling data of three well pads (pads 123, 127 and 137). The drilling was performed in the following sequence: a bulldozer profile was passing through diluvial-eluvial friable rock at place of a hole, and then it went deeper to primary rocks through mined tunneling to the depth of approximately 5-6 m. Then, hole drilling was further done from this trench with layer-by-layer rock excavation (ore).

A special attention was paid to testing of these holes. It was done while drilling using various sampling techniques:
- trench sampling in sections of 0.9-1.0 m long was performed for each of four hole walls;
- cutting sampling of roller-bit drilling of wells, located along the X-shaped section area (5 points in total – 4 on hole corners and 1 in the center), was performed every meter while drilling;
- meter-long core samples from close-paired wells with a drill bit diameter of 96 mm and 131 mm were collected;
- 10 bulk samples (BS) each weighing 10-11 kg were collected at every meter of a hole sink rate through grab sampling;
- 5 grab samples (GS) each weighing about 10 kg were collected parallel to bulk sampling.

The purpose of trench sampling was to collect the statistical data ensuring, firstly, the reliability of its results, and, secondly, the comparison of results of this sampling to bulk, grab and especially core samples of wells associated with a hole. Two contiguous subparallel channels were made along a northwest hole wall to study the representativity and reproducibility of the obtained data. The sampling was done using a fan plate sampler, which ensured the mature section of a channel (10x5 cm).

Overview of a geological structure of the study object.

It is given here according to A.I. Ivanov [2-4] – the discoverer of the Ozherelie field. The field area is composed of metamorphosed terrigenous deposits of the Bodaybo series of the Riphean-Vendian Age represented by Aunakit, Vacha, Anangrskaya and Dogaldyn suites.

The stratigraphic breakdown of rocks composing the Ozherelie field is controversial, which is caused by the absence of limestone marker horizons within a section and complex isoclinal folding of a higher order.

Tectonically, the Ozherelie field is limited to a northeast wing of Marakano-Tungussky syncline of the II order.

Rocks near the Ozherelie field are metamorphosed in the conditions of albite-epidote facies, which is demonstrated by a widespread formation of biotite, garnet, an amphibole (hornblende).

Three main age generations of quartz veins are found in the field. The first generation – premetamorphic veins of linear folding stage, ore mineralization is not present.

Late metamorphic and post-metamorphic veins are characterized by sericite or chlorite present in exocontact. They are divided into two main morphological types. The first type – concordant and subconcordant fissure and often lens-shaped veins formed within the overthrust belt. Such veins are gold-bearing and generally form gold zones. The second morphological type of veins of this age includes cross veins in relation to the folded structure. They are not characterized by industrial gold mineralization.

Kyanite-quartz veins are formed randomly along the entire area of the ore field and are usually sin-metamorphic and are not characterized by useful mineralization. However, the ore mineralized zone No. 1 is characterized by gold-bearing late metamorphic kyanite-muscovite-quartz veins.

The mineralized zone No. 1 has complex internal structure. The veins and veinlets studied within a pit, in ditches, on clearing and a well core represent several generations with different morphology and orientation.
The first and the most ancient generation represents kyanite-quartz veins and veinlets. The minable width of such veins usually does not exceed 0.4-0.5 m, they lie subconcordantly to foliation and lamination, and can cross it at different angles. These veins contribute to the structure of ore veined and veinlet-disseminated zones, often contain visible gold, their gold grade reaches 10-15 g/t and more.

The second ore generation represents brown spar-quartz veins and veinlets generally forming the ore veined and veinlet-disseminated zone.

Gold in veins and veinlets is associated with selvage brown spar rim or relic brown spar rim inside veins.

Besides veins and veinlets, the mineralized zone is characterized by the so-called banded ore representing foliation zones of up to 0.2-0.3 m thick. The richest banded ores 'restrict' from above the ore zone characterized by high gold values. According to panel samples it reaches 200-600 g/t (assay test), according to bulk sampling No. 1 (5.395 t) via the gravity method (quartering to 1 mm and processing on a concentration table) the concentration of extracted gold made 141.4 g/t. Gold in banded ores is associated with brown spar veinlet margins and, more often, with muscovite-brown spar shale formed within contacts or inside the zone of these ores.

The third and fourth generation of veins and veinlets are considered post-ore.

The field is developed via trenches, core holes 122, 96 and partially 76 mm along 50х50 m network with core sampling every 1 m. Gold in the mineralized zone is quite coarse. According to screen analysis, the bulk samples revealed that 70% of gold particles are more than 2 mm, including 13-18% – more than 7 mm. Often, the gold grains reach 20-40 mm. This confirms quite random distribution of gold and low probability of coarse gold grains getting into standard samples, mainly core samples, due to small sample volume.

3. Data validation

Due to high complexity of geological structure and quite random distribution of gold, at the very first stages of prospecting and evaluation works within the Ozherelie field the contractors had some doubts regarding the possibility of using the data obtained while drilling for a reliable delineation and reserves estimate. The doubts were caused not so much by exploration errors (for example, low core recovery) but by coarse gold present in ores, its quite random distribution, presence of nests and lenses with high concentration of gold, i.e. factors reducing representativity of samples with different volume and section within the affected zone. The mentioned features predetermine high variability of gold concentration, considerable asymmetry in its distribution, which has an absolute negative effect on the accuracy of geometrization of ore zones, imposes material constraints on classical methods of data analysis and control.

It should be noted that data validation is a standard approach that includes verification of source data, conformance check of test parameters to specification, internal and external testing control, definition of random and systematic errors, bulk sampling, etc. Verification and validation of the obtained data usually follows the comparison of individual samples and their average grade, which on the one hand makes the approach too simple, and on the other hand does not fully utilize the valuable geological information requiring considerable effort. To our opinion the data validation shall include additional stages (evaluation criteria):

1. Study, comparison of gold distribution laws and their reproducibility by various tests.
2. Assessment of divergences of distribution parameters (average, dispersion, grade variation, asymmetry, kurtosis, mode, distribution median), which is based on gold distribution laws.
3. Statistical estimation of reproducibility of trends (regularities) of gold grade change at depth along trenches and wells.
4. Statistical estimation of similarity of interval test data according to contiguous trenches and wells.
within a single altitude interval.

The study of gold grade distribution laws within the test site by sampling types in holes 123, 127, 137 (bulk, grab, trench, and core sampling with different diameter of a drill bit), as well in contiguous (pad) wells showed what generally all sampling types result in almost similar distribution (Figure 1), but with insignificant differences in numerical characteristics. This provoked the conclusion on their representativity according to the condition of the first and second sampling stages [12].

![Figure 1. Distribution of gold grade by sampling types.](image-url)

The third criterion is reproducibility of trends (regularities) of gold grade change at depth along trenches and wells. In this case, the visual analysis is quite problematic due to high variability of gold concentration and its fair subjectivity, hence this requires a special approach based on comparison of autocorrelation functions [13, 14]. The analysis thus made showed that all types of core sampling reveal natural change of gold concentration at depth, since autocorrelation functions for close-paired wells have similar structure and layout. Thus, the presented sampling types may be considered representational.

The fourth criterion – estimation of similarity of interval test data according to contiguous trenches and wells within a single altitude interval, which is often limited to the calculation of pair correlation, double difference, and sometimes to visual analysis. It is worth noting that almost all mathematical methods of data comparison and analysis are based on the assumption of normality of the distribution law of total population, popularity and similarity of dispersions, etc. If the distribution law is different from the standard normal one and it is impossible to verify the regularity of dispersion and equality of mathematical expectations, the use of non-parametric tests and the most frequently used criteria of equality of means (Student) and dispersions (Fischer) is not reasonable, since they prevent the correct estimation of differences.

One of quite simple and frequently used methods to check data similarity is the correlation analysis studying linear connection between two-dimensional random variables. However, the correlation theory is based on a two-dimensional distribution with symmetric probability density. In other words, conditional distribution laws of continuous random variables constituting a system shall be normal. The correlation theory for asymmetric distribution may have false result, since the hurricane samples (HS) or abnormally
high grade extinguish the correlation to the point of its disappearance. To some extent, it is possible to tackle this phenomenon through the restriction of influence of abnormal values (emissions) in samples [15].

Let us estimate the reliability of stochastic functions based on the theory of random functions (validation of mathematical methods to study mineral deposits is contained in work [16]).

The cross-correlation function (CCF) is a more detailed and flexible tool to study the correlation. It considers structural changes of ore-bearing layers in heightwise position, and the standard paired correlation coefficient is the CCF special case when the log equals zero.

Let us consider the results of such analysis. Theoretically, when comparing the sampling data for two neighboring wells the similarity point on a diagram shall reflect the log that equals zero, if samples are placed at a similar hypsometric level and there are no significant structural changes between location of wells. Figure 2 shows the case of good consistency of results for two sampling types regarding wells with diameters of 131 mm and 96 mm without abnormally high grades.

![Figure 2. CCF between wells without hurricane samples.](image)

Figure 3-a illustrates a different scenario when the correlation at zero log is slightly negative, which confirms the lack of similarity between sampling data for wells with the diameter of 131 mm and the first trench drilled NW to a hole wall. In this situation a geologist shall come to an unambiguous conclusion: one of the sampling types is unrepresentative. In fact, this is by no means always the case. The conclusion will be false. The sampling data on a trench contains a hurricane sample of 138 g/t. If the influence of the anomalous sample is limited, the situation changes dramatically (Figure 3-b). As a result, we see that these samples are quite similar, their correlation is essential, the cross-correlation coefficient equals 0.57. In this case the conclusion will be the opposite: both sampling types are representative.
Thus, to ensure the correctness of mathematical methods and hence, correct estimate of reliability of exploration data within gold fields, there is a need to restrict the influence of hurricane (abnormally high) samples.

Definition and accounting of hurricane samples.

The second problem, which had been announced at the beginning of the 20th century, failed by now to get its satisfactory theoretical solution [15], which would be recognized by geologists and the global scientific community. The published methods (over 40) cannot be considered uniform, they are rather empirical, and their theoretical insights do not consider the multi-factor origin of hurricane samples. Nevertheless, the above problem shall be by all means solved in practice, and more often discretionary, i.e. by applying that way of restriction, which is acknowledged by TRC or SRC. Modern GIS, which are used for geometrization, digital modeling of fields and reserves estimate, utilize a foreign approach similar to the one proposed by the Russian geologist P.L. Kallistov, where the source sampling data are ranked in ascending order and the last 3 samples, which are 2-3 times different from the previous ones, are rejected or replaced with a threshold value.

When utilizing various methods to define and account the hurricane samples it is necessary to consider two areas of their application:

Figure 3. CCF between well of 131 mm and NW trench with and without a hurricane sample.
1. Limited influence of high samples to ensure correctness of mathematical methods for exploration data analysis and testing.

2. Limited influence of high samples for reserves estimate.

In the first case it is critical to find and limit the HS influence using one of the published methods. The accuracy of calculation and the limit value (threshold) are not fundamentally important. The main task is to reduce the influence of a hurricane sample thus improving the correctness of mathematical methods and achieving the maximum likelihood of obtained results.

In the second case it is essential to diagnose hurricane samples and to define the boundary of their influence as accurately as possible, since the case concerns average concentrations, and hence gold reserves.

The study of the Ozherelie field using simulation modeling showed that except the abnormally high samples (AHS) there are also abnormally low samples (ALS), which shall also be considered to maintain the statistical balance of concentrations within the estimated subsoil site. The designed simulation mathematical model of the field was used to study the overestimate/underestimate of an average sampling grade (expressed as \( K \) coefficient representing the correlation of a sampling average to the general) depending on statistical parameters and different sampling volumes. It turned out that there is a statistical relation between coefficient \( K \) (vertical axis) and the grade variation coefficient of sampling.

![Figure 4. Dependence of \( K \) on grade variation, \( \sigma_{\ln} = 0.735 \).](image)

It is worth paying attention to one key feature – the diagrams show that the point cloud crosses the line \( K = 1 \). Thus, the average grades cannot only be overestimated at high variation coefficients, but also be underestimated at low variation coefficients as was noted in the book by M. David [8, 17]. This leads to the fact that some ore blocks may be incorrectly classified according to the valuable element: nonindustrial blocks are classified as industrial and vice versa. Such situation was often observed during the development of rare and non-ferrous metal fields.

Thus, this leads to fundamentally new approach to accounting of hurricane samples, namely the need to correct not the individual samples, but the average samples where the latter ones shall be increased up to a certain variation coefficient (accounting of abnormally low grades) with their further reduction (accounting of abnormally high grades). In the given example, the transition point from underestimate average sampling to its overestimate corresponds to the variation coefficient of 180% for 30 and 10 sample take-off. In this regard, it is reasonable to consider that the hurricane samples include not only high grade, but also low grade samples.
| Elevation point | Cut-off grade, g/t | Elevation point | Cut-off grade, g/t |
|----------------|-------------------|----------------|-------------------|
| 775.45         | 0.094             | 774.98         | 0.909             |
| 774.50         | 0.500             | 773.09         | 0.589             |
| 773.55         | 0.186             | 771.67         | 0.656             |
| 772.60         | 0.101             | 770.73         | 1.476             |
| 771.65         | 0.286             | 769.77         | 0.547             |
| 770.70         | 0.386             | 768.82         | 0.20              |
| 769.74         | 0.226             | 767.87         | 0.290             |
| 768.79         | 0.263             | 766.92         | 0.637             |
| 767.83         | 0.100             | 765.97         | 0.463             |
| 766.87         | 0.132             | 765.02         | 1.047             |
| 765.91         | 0.305             | 764.06         | 0.524             |
| 764.95         | 0.112             | 763.11         | 0.568             |
| 763.99         | 0.095             | 762.16         | 0.171             |
| 763.04         | 0.147             | 761.20         | 2.039             |
| 762.08         | 0.044             | 760.25         | 0.462             |
| 761.12         | 0.391             | 759.29         | 0.497             |
| 760.16         | 0.441             | 758.34         | 0.401             |
| 759.20         | 0.140             | 757.39         | 0.216             |
| 758.24         | 0.235             | 756.43         | 17.484            |
| 757.28         | 0.156             | 755.48         | 20.303            |
| 756.33         | 2.634             | 754.52         | 11.301            |
| 755.37         | 2.634             | 753.57         | 7.985             |
| 754.41         | 3.116             | 752.61         | 3.454             |
| 753.45         | 3.423             | 751.66         | 1.203             |
| 752.49         | 1.593             | 750.70         | 2.072             |
| 751.53         | 5.780             | 749.75         | 1.167             |
| 750.58         | 0.742             | 748.79         | 0.631             |
| 749.62         | 0.340             | 747.84         | 0.635             |
| 748.66         | 0.276             | 746.88         | 1.138             |
| 747.71         | 0.172             | 745.93         | 0.452             |
| 746.75         | 0.183             | 744.97         | 0.570             |
| 745.79         | 0.170             | 744.02         | 0.566             |
| 744.83         | 0.080             | 743.06         | 0.393             |
| 743.88         | 0.076             | 742.11         | 0.549             |
| 742.92         | 0.117             | 741.15         | 1.127             |
| 741.96         | 0.297             | 740.19         | 1.049             |
| 741.00         | 0.210             | 739.24         | 0.377             |
| 740.04         | 0.090             | 738.27         | 0.542             |
| 738.08         | 0.110             | 737.33         | 0.362             |
| 737.17         | 0.093             | 736.38         | 0.290             |
| 736.21         | 0.174             | 735.42         | 0.793             |
| 735.25         | 0.056             |                 |                   |
As can be seen, the problem of HS diagnostics and accounting (AHS and ALS) is still relevant and requires urgent solution, since it is typical for both ore and placer fields of metals and gemstones.

Definition of top and bedrock position.

High variability of gold concentration, discretization and nesting of distribution, presence of coarse gold, and cut-off limits affect the accuracy of top and bottom boundaries of ore zones, bodies and deposits. Let us illustrate this with an example of the Ozherelie field.

Table 1 shows the sampling results on wells 103 and 103A with only one-meter distance between wellheads. Delineation was performed for the following cut-off grades: 0.2, 0.4, 0.6, 0.8 and 1.0 g/t taking into account the following: void band of 5 m, cutting depth of 5 m at average concentration for the given interval is not lower the cut-off grade and, respectively, the minimum cut-off grade of 1.0, 2.0, 3.0, 4.0 and 5.0 GT/t.

The analysis of delineation results at various cut-off grades showed a considerable difference in the boundaries of ore zones in certain wells and within one pad. In the given example, the difference in the top boundary of an ore zone makes 0.5 m, bottom boundary – 16.5 m, which increases significantly with the increase in cut-off grades.

Thus, at the cut-off grade of 0.4 g/t the absolute error of defining the top and bottom of a deposit makes 14.8 and 17.9 m.

The increase in the cut-off grade up to 0.6 g/t leads to deposit split for well 103-A into two ore bodies. The difference in top and bottom boundaries for the first one made 18.65 and 3.70 m, and the second was not defined by the first well at all. The difference of boundaries at 0.8 m cut-off grade made 9.64 and 4.65, at 1.0 m cut-off grade – 0 and 4.65 m. If in this particular example the definition error of the beginning of the mineralization zone (at 0.2 g/t cut-off grade) is quite small, then for other cluster wells it reaches the same orders as for the bottom layer.

4. Results and discussion

What can be the reason for such high definition errors? First, high variability of gold concentration caused by its extremely uneven distribution (close to lognormal observations law) in the mineralization zone (Figure 1), particle distribution asymmetry of gold grains and sample geometry when the core area (hence, coverage area) is quite small. The dispersion in well 103 equals 1.33, then in well 103A located only one meter away from well 103 it made 17.94, i.e. 13 times more. It is obvious that on a compositional level the ore grade mineralization is bound to quartz veinlets and nests. The obtained results show that the distance between nests may reach one meter or less.

The second factor defining the ambiguity of contouring is the natural random variability [16] connected with the first factor and obfuscating the existing regularities along a wellbore. The absence of random variability results in no need to define the contour along a wellbore. However, in this case the primary error will be the geological error [16], i.e. the error of propagating the sampling data along the well into the crosshole space. This entirely depends on the distribution nature and concentration points of gold particles, which is reflected in the table where despite high regularity of well 103A (Figure 3), the contours of an ore body and the contours established for well 103 are different.
The dispersion of random variability calculated according to second differences [18] made 0.80 for well 103 and 3.05 for well 103A. This means that in the first case, the random variability in general is equal to 48%, and in the second – to 17%, i.e. the regular variation in well 103A is stronger. This feature may also be reflected in diagrams of autocorrelation function [11, 14, 16]. Figure 5 shows the geological error reflected by autocorrelation coefficient at log equal 1, and the nature of regular variation along the well bore – by dynamics of autocorrelation function.

This is applicable for all samples without exception. The study showed that for high-contrast fields the random definition error for the deposit top may vary from 5 to 20 m using the current exploration studies, i.e. from one to nearly four 5-meter ledges, which results in considerable mining losses or dilution. It is obvious that it will negatively affect the entire mining complex: overburden removing and mining, as well as processing. The solution of the above problems is critical to increase the overall performance of a mining plant.

Most often it is suggested to solve the given problems by increasing the sampling volume, splitting the exploration clearing, verifying with bulk samples, ensuring more careful sampling and control over its grade, maintaining a closer network of production sampling. All listed approaches are expensive and lead to considerable rise in price for end-products, while the increase in sampling volume leads to certain technical constraints. The experience showed that the massive improvement is not observed even if the mining plant goes into additional spending.

A careful study of experimental results within the Ozherelie field made it possible to conclude that the majority of problems may be tackled by a simple engineering solution – drilling of close-paired wells with double rarefaction of an exploration grid. What will it result in?

1. More exact heightwise definition of top and bottom of a deposit.
2. Reduction of contouring ambiguity within a section, between sections and in the plan.
3. Increase in accuracy and reliability of reserves estimate.
4. Increase in mineral recovery rate, reduction of losses and dilution, including technological ones due to ore quality improvement.
5. Ore and metal reserves increment.
6. Reduction of drilling footage per one well.

**Figure 5.** AKF along wells (1 m distance).
The last item requires further explanation. We performed some works on the experimental block to study the change of reserves depending on the method of average contour definition (for two, three, four or five wells) at various cut-off grades. The results were impressive (Figure 6).

![Figure 6. Diagram of ore width change from the number of delineation wells.](image)

The average ore contour only for two close-paired wells demonstrates a reserves increment from 19 to 34% thus reducing the metal losses.

5. Conclusions
There is a high risk of losing some reserves due to high contouring error (top and bottom) for ore zones or bodies concerning gold fields, which are characterized by nesting distribution of a valuable element, lack of clear lithologic control when the mineralization zones are defined according to sampling data.

To reduce errors related to contouring there is a need to change the exploration method of such fields and to ensure its operation through the close-paired wells. The position of a contour may be chosen either as an average location between two obtained contours for two wells or as the maximum productivity of these wells. Which option is more acceptable is still an issue requiring further study. However, it is clear that the duplication of wells will provide for higher contouring reliability and reduction of concealed losses and dilution [10] thus increasing the subsoil use.

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