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Mosaic blockiness of discrete subsystems of stockwork gold mineralization, Jerooy deposit (Kyrgyz Republic)

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Abstract

Relevance. Due to the depletion of near-surface deposits with rich ores, the problem of developing methods for exploration and evaluation of poor ores has become urgent for the involvement of off-balance deposits in exploitation. Research based on the paradigm of "discrete" as a promising scientific direction against the "continuous" type of mineralization used in practice.

The objective is to identify characteristics of the block organization of mineralization based on fractality.

Research object – Jerooy stockwork gold-quartz deposit (Kyrgyz Republic).

Methodology and techniques – measuring fractality using the cell method; measuring the discreteness of hierarchical taxa; mosaic block size and distribution of core blocks, mineralization periphery and barren blocks. Methods: measuring discrete subsystem blocks; measuring mosaicity using the exploration model of operational exploration of a stockwork fragment measuring 220 x 80–100 m x 100–180 m, exploration drillhole network 20 x 20 m; 66 boreholes > 6000 core samples. Geostatistical, gold distribution, graphical and analytical methods for measuring blocks.

Scientific hypothesis. Mineralization is represented by a self-similar hierarchy of discrete subsystems (by dimension *N* x 1000 m; x 100 m; x 10 m; x 0.01 m), consisting of equivalent mosaic structures in discrete subsystems, which is a regular block organization of mineralization.

Results, scientific novelty. Formation, distribution and placement of blocks: mineralization cores, transition zones and barren zones have a self-similar identical in distribution and distribution of blocks in subsystems – a regularity of discrete subsystems; suitable for substantiation of new approaches to the methodology of exploration and evaluation of gold ore deposits.

***Keywords*:** Discreteness, mosaicity of mineralization blocks; fractality; core, periphery and barren blocks.

Introduction

Relevance. The depletion of near-surface deposits with rich ores actualizes the need to develop methods for exploration and evaluation of poor ores for their involvement in exploitation based on the fractal regularity of the organization of the geo-environment and mineralization – a study of the paradigm of "discrete" mineralization versus "continuous". Justification of methods and approaches to new quality of mineralization evaluation and exploration, primarily for poor ores.

Literature review. The theory of open self-organizing systems – non-linear geodynamics and synergetics are associated with the studies of: I. Prigogine, S. P. Kurdyumov, G. Haken, A. A. Samara, G. G. Malinetsky, B. Mandelbrot; the block-hierarchical structure of ores was studied by M. A. Sadovsky, V. V. Piotrovsky, V. I. Ulamov, S. V. Goldin, G. G. Kocheryan, P. V. Makarov, V. N. Rodionov and others. To the fractality of mineralization are devoted the works of P. M. Goryainov, A. M. Pavlov, V. I. Snetkov, D. L. Turcotte, V. A. Filonyuk and many others.

The purpose of the work is to establish parameters of mosaicity of block organization of mineralization in discrete subsystems of the hierarchy of self-similarity.

Tasks. Mosaicity; characteristics of mosaicity, distribution; influence of mosaicity on technology, geotechnics and geotechnology of development of block organization of mineralization.

The object of study. Stockwork ore bodies of the Jerooy gold-quartz deposit (Kyrgyz Republic).

Methodology. "The new concepts of the structural state of the geological environment are based on the priority of the "discrete over the continuous". Individual components of the geological environment (the spatial distribution of gold in the ore bodies of gold deposits, the distribution of the intensity of manifestations of fault tectonics and fracturing in rock massifs and the structure of shear zones, etc.) have a complex, regular, intermittent nature. The most characteristic properties of the geological environment also include the hierarchy of all its components. Hierarchical levels (hierarchical system of levels)

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are systemic formations in which discrete elements of the next higher scale level act as objects considered as systems at the previous scale level. This is the main element of the structural organization of the feature space of the geological environment as a spatially ordered set of elements that impart stability and taxonomic certainty to it due to the geometrically formalized order of the spatial inclusion of discrete elements of different scales into each other" [1].

Identification of characteristic properties of the geological environment by hierarchical components, forming discrete elements including self-similar subsystems and creating ordered taxonomic systems of geometric order. Establishment of parameters of structural matrices, controlling the discreteness of mineralization for identification and accounting of the complexity of the internal structure of industrial ores, regularities at local scale levels of the structural organization of contours and concentrations of mineralization – ore body, block, lens, nest [1].

Methods. Measurement of blocks and mosaicity using the exploration model of operational exploration of a stockwork fragment measuring 220 × 80–100 m × 100–180 m, exploration network of drill holes 20 × 20 m; 66 holes: > 6000 core samples. Geostatistics, gold distribution, graphical and analytical methods of block measurement. Identified discrete subsystems of mineralization mosaicity by the main discrete subsystems N × 1000 m ... × 100 m … × 10 m × 0.01 m.

The object of study and structural-kinematic prerequisites for ore localization

The main fault structure of the deposit is the Ichkelitau-Susamyr regional paired fault (ISF), the northern seam of which is represented by the southern boundary of intensive gold-quartz mineralization [3]. The ore cluster and the deposit have a close spatial connection and are determined by the local dome structure of the Chichkan-Kolbinsky batholith [4].

In the immediate vicinity of the Severo-Ichkelitau fault deposit, the most important deep structure of the region with an ancient origin and a long history of development (before the Quaternary) changes direction from NW to sublatitudinal, making a significant bend, fig. 1 (bend of the fault to the south of the figure).

During the pre-ore stage, a tectonic environment arose near this bend that was favorable for the formation of sub-parallel fault delaminations in the form of chains of sinuous rupture cracks, which, in combination with the feathering cracks of the north-western (NW), submeridional (SM) and north-eastern (NE) directions, formed a weakened zone, which subsequently localized mineralization and predetermined the structure of the ore zone as a whole, the morphology of individual ore bodies. In addition to the general deformation of the bend, many accompanying factors influenced the formation of the most complex in outline weakened sections of the zone, which later manifested themselves as ore bodies, such as local stresses along large meridional faults filled with dikes, different elasticity of rocks, etc., fig. 1.

The occurrence of geotechnical conditions of tension is associated with the arcuate shape: "tensile structures in plan often have arcuate outlines" [5]. "In the theoretically most complete version, the separation of a block from the main massif and its movement to the side with reduced resistance is accom-

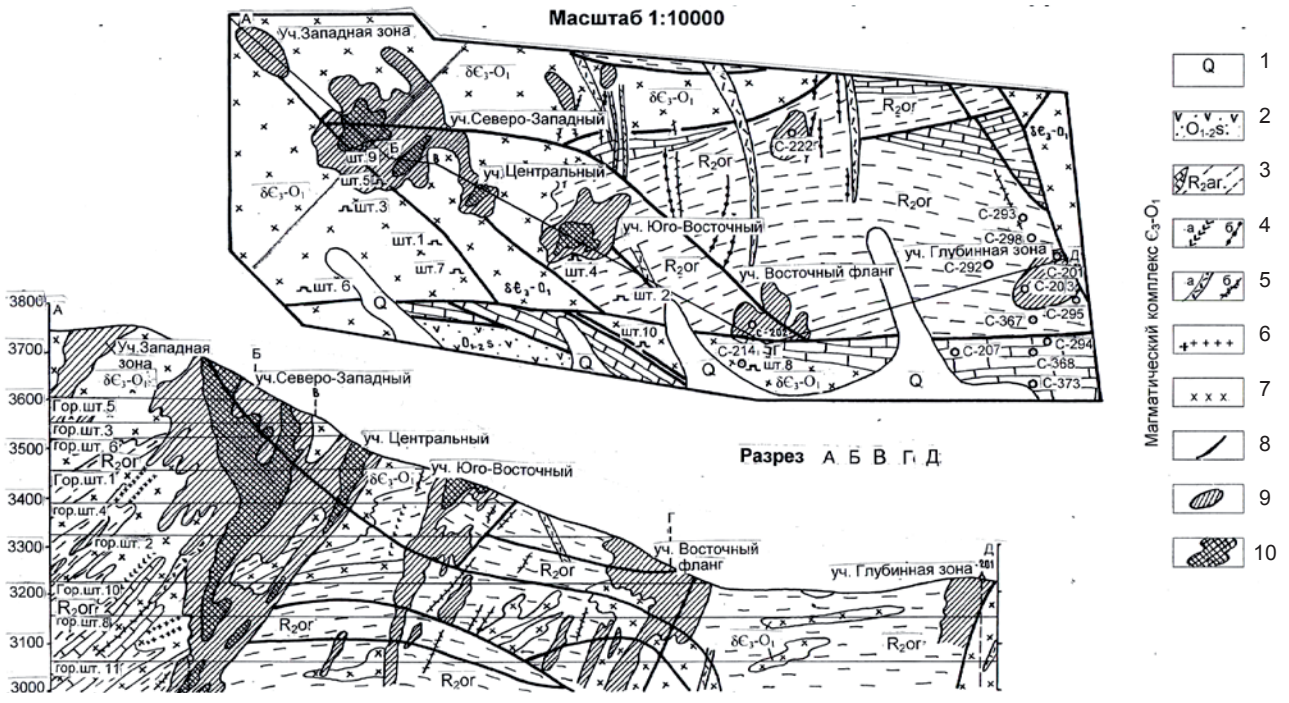

Figure 1. Geological map of the Jerooy deposit, scale 1 : 10 000 [2]: *1* – Quaternary sediments; *2* – Andesite porphyry tuffs (O_{1-2}); *3* – Dolomites, quartz-mica schists, sandstones (Rar); Igneous complex {C_3–O_1): *4* – Diabase porphyry dikes (a), spessartites (*б*); *5* – Quartz porphyry dikes (*а*) and plagioporphyries (*б*); *6* – Aplite veins; *7* – Quartz diorites; *8* – Faults; Ore bodies: *9* – with an Au content of over 1 ppm; *10* – Ore bodies with an Au content of over 2 ppm

Рисунок 1. Геологическая схема месторождения Джеруй, масштаб 1 : 10 000 [2]: *1* – четвертичные отложения; *2* – туфы андезитовых порфиров (O_{1-2}); *3* – доломиты, кварцево-слюдистые сланцы, песчаники (Rar); магматический комплекс (C_3 –O_1): *4* – дайки диабазовых порфиров (*а*), спессартитов (*б*); *5* – дайки кварцевых порфиритов (*а*) и плагиопорфиров (*б*); *6* – жилы аплитов; *7* – кварцевые диориты; *8* – разломы; рудные тела: *9* – с содержанием Au свыше 1 г/т; *10* – рудные тела с содержанием Au свыше 2 г/т

modated by the formation of a round-spherical or cylindrical surface along which stresses will be distributed in accordance with J. Anderson's rule regarding the kinematics of differently oriented shears; in plan, this rounded surface will look like an arc, at the apex of which tension is concentrated, and on the flanks, shears may also form…" [5].

According to the material composition, the ores of the Jerooy deposit belong to a single industrial type – quartz-gold ore poor sulphide. The number of sulphides does not exceed 1%. According to geological data, the ore bodies are represented by quartz veins, veinlets in altered enclosing granodiorite. The main ore component – gold – is distributed in the ore quartz in the form of tiny disseminations. Therefore, the metal content in the ores, as a rule, is directly proportional to the degree of silicification. In the central highly silicified areas of the ore bodies and in the quartz cores, the gold content usually fluctuates from 5 to 30 ppm, very rarely reaching 50–100 ppm. In the weakly silicified peripheral areas of the ore bodies, it decreases to 1–5 ppm, and the ore bodies themselves are surrounded by a wide halo of weak silicification with a gold content of up to 1 ppm [3].

Review of methodology and theoretical background

The dimension of blocks by the distance between fracture zones and faults is estimated using the Oparin, Kurleni formula, according to the "statistical characteristic of the average distances between fracture zones separating structural blocks from each other – a stable relationship between the values of crack opening and the diameters of the block separated by them in the structural hierarchy of rock massifs [6]:

$$\mu_{\Delta}\left(\delta\right) = \frac{\delta_i}{\Delta_i} = \Theta \cdot 10^{-2}, \quad (1)$$

where δ_i – average "opening" of cracks (distance between their edges), Δ_i – the diameter of the blocks of the i-th hierarchical level, and the coefficient Θ most often falls for any i in the interval 1/2–2, i. e. Θ Î (1/2 – 2) [4, 6].

Including, based on dozens of developed formulas of hierarchical discrete series of blockiness, for example: G. G. Kocharyan and A. A. Spivak [7], with reference to the results of studies by M. A. Sadovsky [8, 9] and V. V. Piotrovsky [10], give a relationship that determines the corresponding size of the block L_n in the hierarchy of scales:

$$\begin{cases} (3–6)10^{\left(\frac{n-11}{2}\right)}, \text{для } n=(2k-1), \\ (1–2)10^{\left(\frac{n-11}{2}\right)}, \text{для } n=2k. \end{cases} \quad (2)$$

Here k is an integer ranging from 1 to 9; L_n is the characteristic size of a block of order n, measured in kilometers. In this formula, the highest order of the hierarchy is 18 for k = 9 and leads to block sizes $L_{18} \approx (10 – 20) \cdot 10^3$ km, characteristic of lithospheric plates. The minimum block scale for n = 1 and k = 1 leads to L_1 = 3–6 cm (the next block in the hierarchy, L_2 = 10 – 20 cm, is obtained for k = 1 and n = 2k = 2), etc.

Fractal dimension shows the measure of self-similarity in the studied hierarchical set and the degree of complexity of the structure. The measure of similarity is estimated by the range of scales, where each subsystem fulfills a homogeneous power law, and the relative degree of complexity is determined by the absolute value of the fractal dimension. [1, 11, 12].

Discreteness

By fractal and block organization of mineralization systems is meant the development of ore systems at different scale levels or regularly manifested characteristics of mineralization blocks.

Block-hierarchical structure of rocks, massifs of the concept of M. A. Sadovsky: "The key role is given to the linear coefficient of nesting of geoblocks of adjacent hierarchical levels" [6, 13]. Statistical characteristics of average distances between cracks separating structural blocks from each other to the diameters of these blocks are defined as a nonlinear process of mineralization. Mathematical development and detailing are determined by fractality, discreteness of block distribution and mineralization, mosaic invariance of ore and barren blocks [1, 14–19].

Blockiness

It is precisely the block hierarchical structure of deformable solids and environments (which has already been actually substantiated by the experimental data accumulated to date, which will be demonstrated in the course of the presentation) that is also evidence that there is no fundamental difference between brittle and plastic materials and environments or between the plasticity exhibited by loaded metals and the destruction of geomaterials and geoenvironments, if we analyze these destruction processes from the point of view of the evolution of hierarchical systems and synergism (which does not exclude specifics of specific physical mechanisms).

Thus, loaded materials and environments are considered as nonlinear dynamic hierarchically organized systems, the evolution of which under external influences occurs according to the laws of synergy. Moreover, the evolution of loaded solids and environments is considered as a special case of the general theory of evolution [17].

Such a general evolutionary theory of open self-organizing systems is currently being developed as nonlinear dynamics of various systems [16, 18, 20–24]. The ideas, methods and approaches of nonlinear dynamics applied to deformable solids clearly indicate that solid media are among the most striking examples of systems self-organizing under external influences [16].

Invariance of blocks

Disintegration and decompaction/dilatancy of the medium/rock massif are determined by the components of the system in which different loading conditions (stress and strain) develop in the subsystems along the inclusions of rigid or soft/yielding blocks (stiff and rigid inclusions). In a rock massif that includes compliant/soft blocks, when they are loaded from a more rigid rock massif, destruction without a dynamic component prevails at the moment they reach the strength limit, which is caused by the accumulation of cracks in them. These blocks represent a fractured medium. In this case, the load on such blocks is distributed in such a way that they are loaded in the mode of specified deformations. And with soft loading, implemented in a rock massif that includes rigid blocks, the entire load is concentrated on them. And when the external load reaches the value of their strength, all the energy accumulated in the surrounding massif is abruptly discharged into

the emerging cracks or into the prepared/existing center of destruction with the maximum concentration of cracks in it, or into the Griffiths-sized crack existing in the structure, and the destruction proceeds brittlely with dynamic manifestations – the release of energy. That is, in this case, loading occurs in the mode of specified stresses [17, 25–28], fig. 2, *а*.

Mosaic pattern of discrete mineralization contours

Zones of decompression with intensive fracturing are associated with the process of mobilization of ore components from their source, transportation and accumulation in an abnormally concentrated form – a system of conditions for the formation of a deposit. In the upper (seismogenic part of the earth's crust, where mechanisms of elastic-brittle destruction of rocks are realized with the movement of fluids along a system of permeable channels with optimal parameters for ore deposition – hydraulic gradient, temperature gradient, stress-strain state of rocks, intrapore pressure of fluid pressure, destruction of mineral aggregates in the fracture-pore space [29–32], fig. 2, *б*.

Concentration cores of mineralization are zones of intense fracturing, probably with superimposed and/or redeposited gold-quartz mineralization. The size of concentration cores of mineralization is determined by the sizes $L_n L$. Probably, morphological and concentration cores of mineralization have a discrete nature of development, manifested by a scaled hierarchy of self-similarity (fractality). On this basis, it is possible to develop a tool for predicting the localization and size of morphological and concentration cores of mineralization based on scaling.

The studies were carried out on the basis of an ore model using a block model obtained as a result of operational exploration of the upper section of the Severo-Zapadny stockwork by drilling exploratory wells along a 20 × 20 m network (10 profiles, 66 exploratory wells) from a horizon of 3600 m to a depth of 60–120 m with the collection of core samples of 1 linear meter and analytical work for gold, determination of up to 0.05 ppm (6578 samples). A frame and block model of mineralization was created according to the gradation > 0.3; > 0.6; > 0.9; < 2.4 ppm; > 2.4 ppm; > 3 ppm; > 5 ppm [33].

To study the discreteness model and mosaic nature of mineralization characteristics, the presented data were allocated by cutoff grade up to 1.46 ppm [32], and by gradation 1.46–2.99 ppm; 3.0–5.99 ppm; 6.0–11.9 ppm; 12.0–23.9 ppm; 24.0–48.0 ppm > 48.0 ppm. The intervals of the presented grades of grades were allocated with the inclusion of substandard breaks with a grade of less than 1.46 ppm up to 2–4 m. Substandard intervals longer than 4 m were allocated as barren breaks. Ore and barren blocks in projection onto a vertical plane along profiles, vertically and in the direction between profiles were morphologically studied for the development of mineralization block contours according to gold content classes and according to the class of substandard contents [33].

The dimension and identification of block mosaicism was made using the method of M. A. Sadovsky [8], the dimension L, m = $\sqrt[3]{L_1 \cdot L_2 \cdot L_3}$, respectively, the length along the strike, thickness and dip. To average the dimension of the blocks, the dimension is expressed in logarithmic form. Discrete subsystems $N \times 1000$ m, etc., where N is an integer from one to nine. The exploration model as a system is comparable in dimension with the stockwork bodies of the $N \times 100$ m deposit, divided into subsystems along ten cross-sections of the 20 m × 20 m operational exploration network. Coordination of ore and barren blocks along the mineralization contours along the wells. The calculations were made based on graphical constructions of the blocks of each section using an analytical method, fig. 3 [33].

Research results

The fractality of deposit blocks (stockworks at a scale of 1 : 10 000) and mineralization blocks (according to the gold concentration in the North-West stockwork body) were previously measured using the square-cell method; for both models, they are tg $a = 20°$, $D = 1{,}36$ [33, 34].

Dimensionality of discrete subsystems based on block measurement results, from the deposit as a system to subsystems – stockworks and their constituent subsystems. Table 1 shows interpolation of mineralization discreteness by dimensionality reduction hierarchy through power function mea-

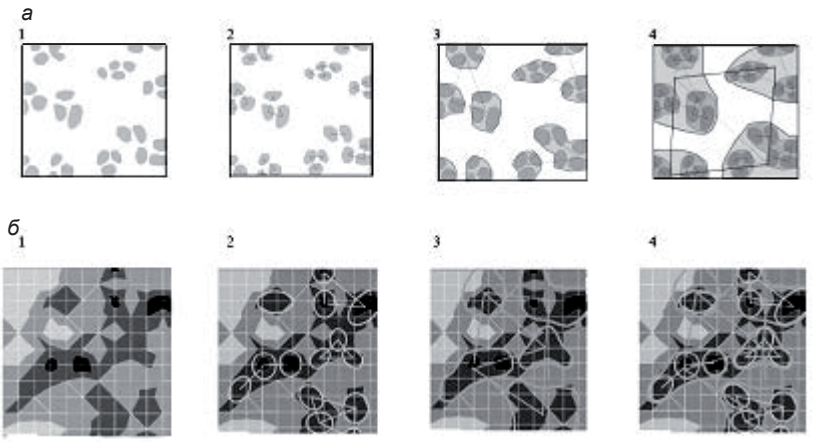

Figure 2. Model examples of sequential (*1*, *2*, *3*, *4*) establishment of a hierarchically ordered cluster structure with fractal properties: *а* – map of distribution of areas of anomalous gold concentrations in the production block; *б* – map of maxima of manifestation of fracturing intensity (cell size 1 m) [1]

Рисунок 2. Модельные примеры последовательного (*1*, *2*, *3*, *4*) установления иерархически упорядоченной кластерной структуры, обладающей фрактальными свойствами: *а* – карта распределения участков аномальных концентраций золота в эксплуатационном блоке; *б* – карта максимумов проявления интенсивности трещиноватости (размер ячейки 1 м) [1]

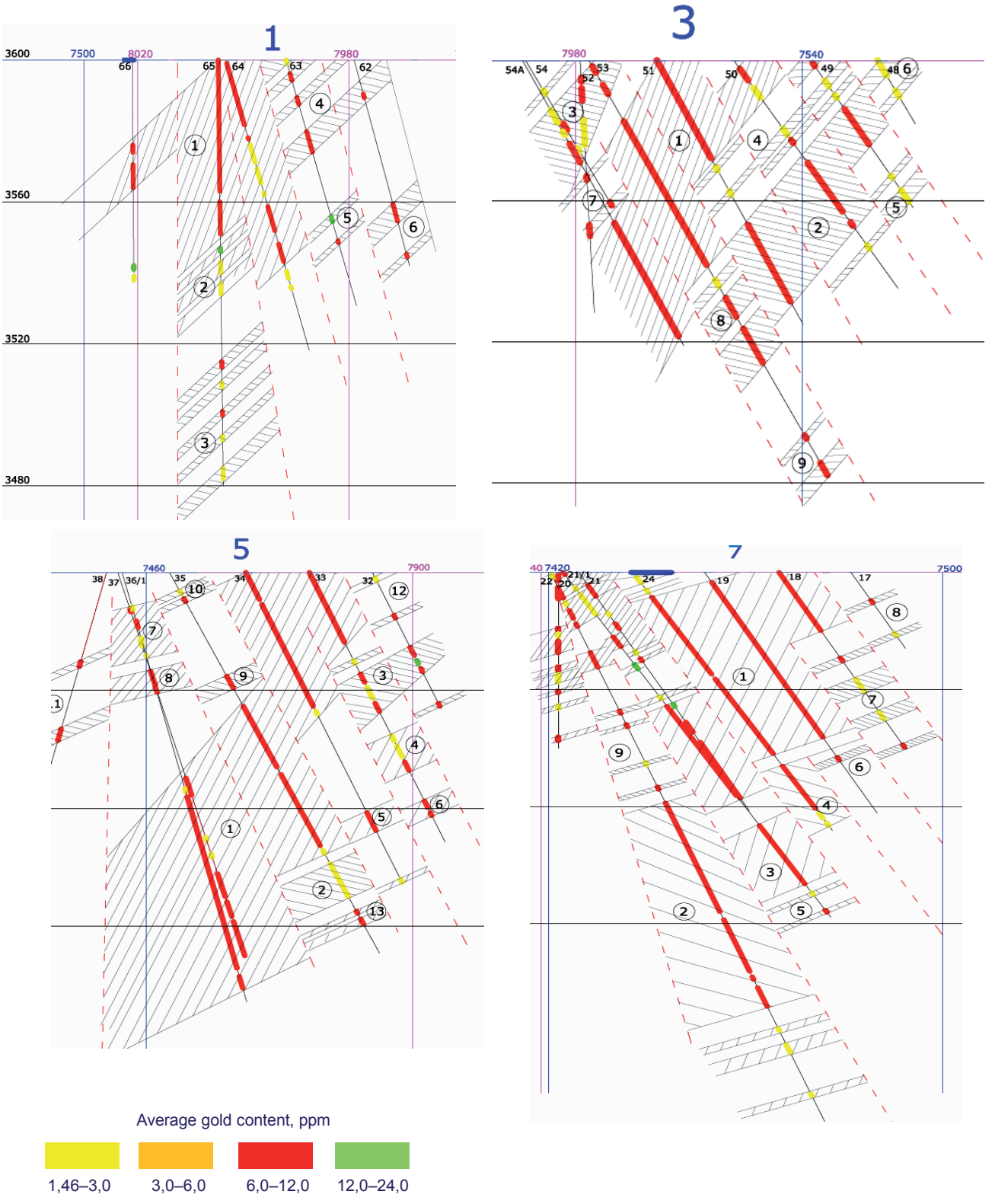

Figure 3. Sections by profiles (*1*, *3*, *5*, *7*), exploration wells, distribution of gold by blocks by grades of content (average per block): shaded areas – ore blocks, no shading – barren and substandard blocks (underground mine resources)

Рисунок 3. Разрезы по профилям (*1*, *3*, *5*, *7*), разведочные скважины, распределение золота по блокам по классам содержаний (среднего на блок): заштрихованные области – рудные блоки, без штриховки – безрудные и некондиционные блоки (ресурсы подземного рудника)

sured by deposit and mineralization blocks. Average value of deposit stockworks – 111.3 m – is taken as average system size. Smallest discrete mineralization subsystem accessible for observation is estimated at 0.02–0.04 m. Hierarchical blocks observed and measured from stockwork to mineralization blocks, interore constrictions and barren intervals from 69.6 to

Table 1. Extrapolation of fractal-hierarchical self-similar subsystems with a power function of 1.2 and a block dimension of 1.6 for fault and fracture zones
Таблица 1. Экстраполяция фрактально-иерархических самоподобных подсистем при степенной функции 1,2 и размерности блоков по разломным и трещинным зонам 1,6

L, m	Ln *L*	Ln/Ln + 1	$\mu_\Delta(\delta) = \frac{\delta_i}{\Delta_i} = \Theta \cdot 10^{-2}$	*L*, m	Ln *L*	Ln/Ln + 1	$\mu_\Delta(\delta) = \frac{\delta_i}{\Delta_i} = \Theta \cdot 10^{-2}$
111,3	**4,70**	1,2	Stockwork	2,10	1,31	1,2	1,6
69,6	**4,20**	1,1	1,6	1,28	1,10	1,2	1,6
41,23	**3,92**	1,2	1,6	0,78	0,91	1,2	1,6
25,11	**3,27**	1,2	1,6	0,48	0,76	1,2	1,6
15,29	**2,73**	1,2	1,6	0,29	0,63	1,2	1,6
9,31	**2,27**	1,2	1,6	0,18	0,53	1,2	1,6
5,67	1,89	1,2	1,6	0,11	0,44	1,2	1,6
3,45	1,58	1,2	1,6	**0,07**	**0,37**	1,2	1,6

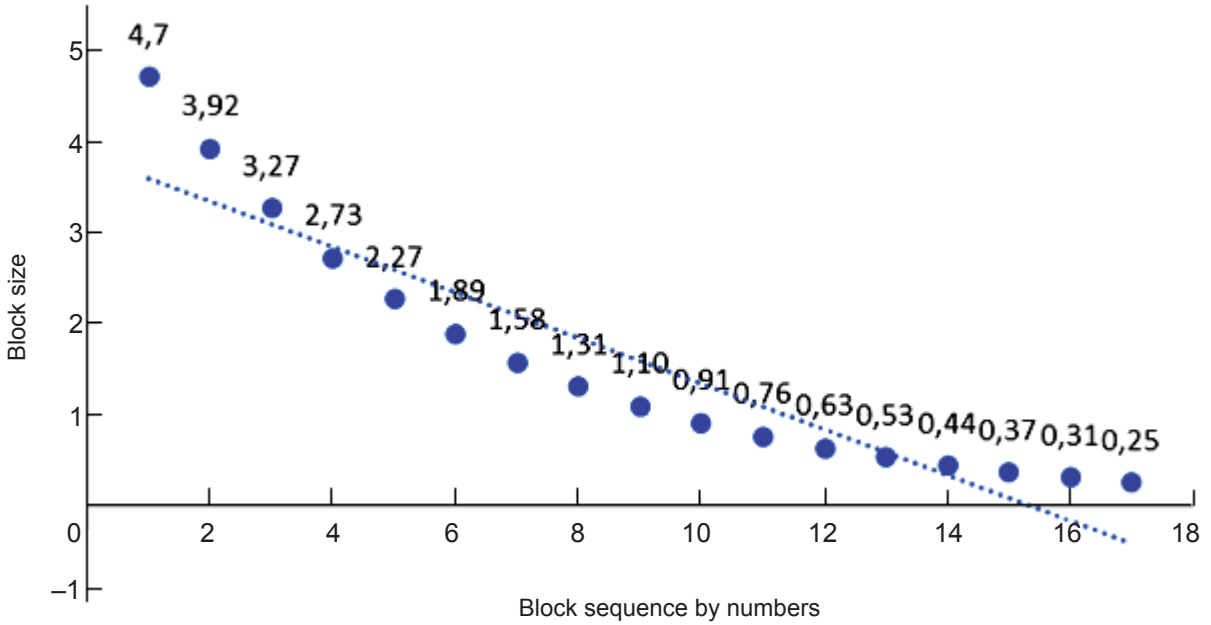

Figure 4. Graph of the slope of the trend of the hierarchy of dimensions of mineralization blocks of the Jerooy deposit, Ln *L* (angle of the trend is 21°)
Рисунок 4. График наклона тренда иерархии размерностей блоков оруденения месторождения Джеруй, Ln *L* (угол тренда 21°)

9.31 m and to smallest observed subsystems from 0.08 to 0.02 m identified during sensory sorting of ores are highlighted in bold in the table. The table shows an estimate of the ratio of the linear dimensions of blocks in the hierarchy, as the average dimensions of inter-fracture zones, according to formula (1) [33, 34].

The equivalence of the measured and reduced dimensions of the hierarchy of subsystems with fractality is shown in fig. 4. Where the trend line of the logarithms of the dimensions of the blocks included in the discrete system of the NW stockwork, through the angle of inclination of the discrete dimensions of the block of 21° as practically identical to the values of the fractal dimension of the discrete subsystems tg *a* (angle Ln *R* to Ln *N* for blocks and mineralization concentrations) is 20° [33, 34].

In general, discrete subsystems form series *N*; *N* + 1; *N* + 2…4, where *N* corresponds to the system and successive subsystems, each successive subsystem is a system for the next element of the series. Systems are designated by the dimension *N* × 1000, where *N* is any integer in the range of the product by the decimal order in meters. To smooth out the spread of dimensions of blocks of a discrete series, they are transformed into a logarithmic form (natural logarithm). For the purpose of identifying mineralization characteristics, the following are determined and measured by various methods: the core of mineralization – ore blocks of intensive mineralization; peripheral mineralization – blocks with a transitional type of mineralization (with local barren constrictions) and barren blocks.

Thus, in a general schematic form, the mosaic nature of mineralization blocks can be expressed at a discrete level, as opposed to the "continuous" type of vision of mineralization distribution accepted in practice at the present time.

The main discrete subsystems of mineralization of the Jerooy deposit and from the dimension of the stockwork bodies

Table 2. Dimensions of the main morphological units of the Jerooy deposit [33, 34]
Таблица 2. Размерность основных морфологических единиц месторождения Джеруй [33, 34]

N	Morphological objects – stockwork bodies	L_1	L_2	$\sqrt[2]{L_1 \cdot L_2}$	Ln L	Degree Ln L/Ln L + 1
1	Jerooy deposit	2058,0	334,0	829,1	6,7	
2	North-West Stockwork (with 1 ppm board)	350,0	294,0	320,8	5,8	1,2
3	Core 1 with 1 ppm board	147,0	135,0	140,9	5,2	1,1
4	Core 2 with 2 ppm board	77,0	35,0	51,9	3,7	1,5
5	Southeastern	176,0	165,0	170,4	5,5	1,0
6	Core 1 with 2 ppm board	89,0	87,0	88,0	4,4	1,2
7	Eastern section	165,0	163,0	164,0	5,5	1,1
8	Central	176,0	47,0	91,0	4,5	1,2
9	Apophysis	118,0	29,0	58,5	3,9	1,0
10	Northeastern	106,0	65,0	83,0	4,4	1,3
11	Deeper	131,0	117,0	123,8	5,0	0,9
12	Western	124,0	65,0	89,8	4,5	1,2

Table 3. Dimensions and distance between stockwork zones of the deposit [33, 34]
Таблица 3. Размерность и расстояние между штокверковыми зонами месторождения [33, 34]

Dimensions of stockworks	L, m	Ln (L, m)	Distance between stockworks	L, m	Ln (L, m)
Western	111,0	4,7	Western		
Northwestern	255,0	5,5	Northwestern	111	4,7
Central	66,7	4,2	Central	89	4,5
Southeastern	111,1	4,7	Southeastern	133	4,9
Eastern	144,0	5,0	Eastern	289	5,7
Deeper	122,0	4,8	Deeper	333	5,8

of the deposit – the main blocks of mineralization of the deposit with the allocation of concentration cores of mineralization at contents of 1 ppm and 2 ppm, with the derivation of the degree of the relationship of the subsystem to the deposit in table 2 ($N \times 1000$ and $N \times 100$).

The mosaic nature of the discrete subsystems $N \times 100$ and $N \times 10$ is detailed on the basis of graphic-analytical measurements of the operational exploration block model.

Mosaicism of discrete subsystems. The block organization of mineralization at the Jerooy deposit is determined by the mosaic distribution and location of ore and non-ore blocks, the first of which is formed from blocks of the mineralization core and transition zones – blocks of peripheral mineralization.

The core of mineralization, blocks with intensive and highly productive mineralization. It is defined as a zone caused by structural-kinematic processes with intensive fracturing. By the nature of fracturing, a continuous zone of tectonic disturbance, which is an ore-localizing and ore-controlling zone with the development of an anomalous zone of ore deposition. Discreteness is distinguished at hierarchical levels from the deposit block system with the development of stockwork subsystems. Zones and blocks of intensive mineralization are distinguished in stockwork subsystems as a quartz core, a core with high-contrast and continuous mineralization. In fig. 1, the deposit block is distinguished as a series of stockwork bodies (seven), in the contour of which contours with a quartz core are distinguished against the background of enclosing diorites, a core according to industrial conditions within the cutoff content of 1 ppm and 2 ppm. In fig. 4 the exploration model of the study core is distinguished by the anomalous gold content of the framework modeling at contents > 5 ppm.

For the purposes of determining the characteristics of the mineralization core within the exploration model for profiles, exploration network models and boreholes, the mineralization core is identified according to the following criteria: 1. Continuity of mineralization with an ore-bearing coefficient > 0.83; 2. By consistent average gold grades over an interval of over 4–5 ppm; 3. By an interval of intensive mineralization over a dip of over 8–10 m.

Periphery of mineralization, blocks of transitional mineralization. Transitional mineralization is geotechnically formed in the zones of transition of intensive fracturing from the core to the host rocks. Characterized by a lower degree of fracturing and, accordingly, the level of mineralization. The main pattern of peripheral mineralization blocks is their

Table 4. Measurement of the dimensions of ore blocks according to the exploration model profiles [33]
Таблица 4. Измерение размерности рудных блоков по профилям разведочной модели [33]

Profile no.	$\sum L_1 \times L_2 \times L_3$	$\sqrt[3]{\sum} = L$, m	Ln *L*	Power function of the general contour of the model
1	56 147,8	38,3	3,6	1,30
2	77 467,8	42,6	3,8	1,30
3	164 673,4	54,8	4,0	1,20
4	198 237,0	58,3	4,1	1,20
5	136 776,8	51,5	3,9	1,20
6	92 516,4	45,2	3,8	1,20
7	151 548,6	53,3	4,0	1,20
8	122 824,4	49,7	3,9	1,20
9	94 109,8	45,5	3,8	1,20
10	81 339,0	43,3	3,8	1,20
Total (90)	1 175 641,0	105,5	4,7	
Average	117 564,1	48,3	3,9	1,20

Table 5. Measurement of barren and substandard blocks according to the exploration model profiles [33]
Таблица 5. Измерение безрудных и некондиционных блоков по профилям разведочной модели [33]

Profile no.	$\sum L_1 \times L_2 \times L_3$	$\sqrt[3]{\sum} = L$, m	Ln *L*	$\sum$ Ln *L*/Ln *l* 1…10	Number of barren blocks per profile	Unit block average	
						L, m	Ln *L*
1	27508	30,2	3,4	1,3	3	20,9	3,0
2	49685	36,8	3,6	1,2	12	16,1	2,8
3	68486	40,9	3,7	1,2	10	19,0	2,9
4	72719	41,7	3,7	1,2	17	16,2	2,8
5	59135	39,0	3,7	1,2	12	17,0	2,8
6	62394	39,7	3,7	1,2	13	16,9	2,8
7	50470	37,0	3,6	1,2	13	15,7	2,8
8	28017	30,4	3,4	1,3	7	15,9	2,8
9	23500	28,6	3,4	1,3	6	15,8	2,8
10							
Total	441 914	76,2	4,3		93		
Average	49 102	36,6	3,6	1,2		17,1	2,8

Table 6. Distribution and dimensionality of the mosaic blocks of the exploration model
Таблица 6. Распределение и размерность мозаичности блоков разведочной модели

Mosaic blocks	V, m³	*L*, m	Ln *L*	V, %
$\sum$ mineralization core	771 143,8	91,7	4,5	47,9
$\sum$ transition blocks	396 395,2	73,5	4,3	24,6
$\sum$ barren	441 913,8	76,2	4,3	27,5
Total	1 609 452,8	117,2	4,8	100,0

own mosaicism in distribution and location – alternation of small blocks of mineralization and barren blocks. Identification criteria: 1. Ore-bearing coefficient less than 0.8–0.6 (individual small blocks with an ore-bearing coefficient defined as $\Sigma n_{ore} / \Sigma N_{total}$ (K_{rud}) of 1.0; 2. Average content of the totality of ore and barren intervals < 2–3 ppm;

Barren blocks. Geotechnically defined by zones, blocks of very low or no fracturing, respectively low degree of mineralization, including silicified and ore substance. Occupy the position of intercontour blocks between the core and peripheral mineralization blocks and within transitional mineralization. Distinguished based on the criteria: 1. Vertical dimension over 5–8 m; 2. Gold content up to 0.5 ppm.

Discrete system *N* × 1000 m – deposit

The presented analysis of the blockiness of areas and morphological cores of mineralization were interpolated with an equivalent method for determining the blockiness by the distance between faults. "The statistical characteristic of the average distances between the crack banks separating structural blocks from each other to the diameters of these blocks is a fairly stable relationship between the values of crack opening

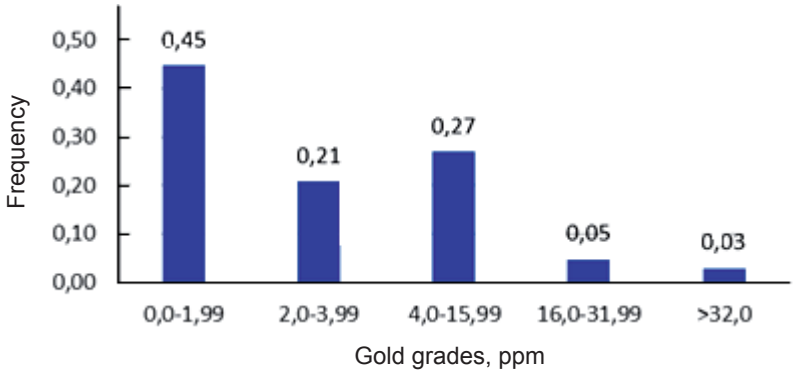

Figure 5. Distribution of gold content by classes, 2146 samples
Рисунок 5. Распределение содержаний золота по классам, 2146 проб

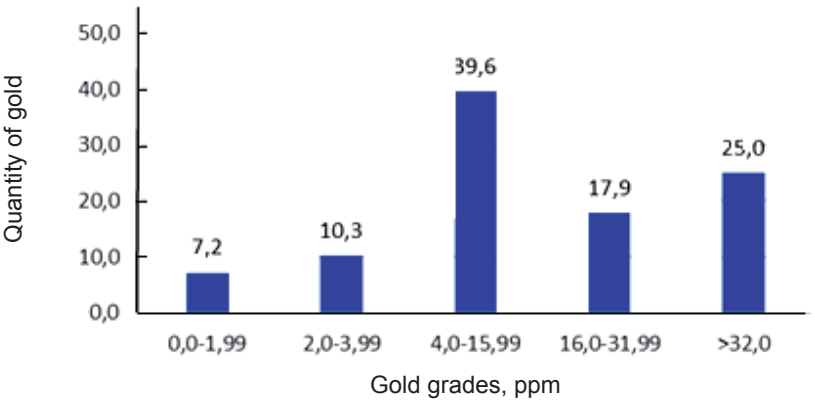

Figure 6. Influence of gold content classes, 2146 samples
Рисунок 6. Влияние классов содержаний золота, 2146 проб

Table 7. Distribution of gold content classes (ppm) and the influence of classes (%), a fragment of the operational block 17-C1 [3]
Таблица 7. Распределение классов содержаний золота (г/т) и влияние классов (%) фрагмента эксплуатационного блока 17-C_1 [3]

Ln *C*	Average gold content, ppm	Class of contents	Distribution, %	Influence, %
–0,03	1,0	0,0–1,99	0,15	1,7
0,99	2,7	2,0–3,99	0,27	8,7
2,12	8,3	4,0–15,99	0,44	43,4
3,14	23,2	16,0–31,99	0,10	28,8
3,56	35,2	> 32,0	0,04	17,5
Total			1,00	

and the diameters of the blocks separated by them in the structural hierarchy of rock massifs" [9]. For further calculations and forecasting the position of mineralization, in addition to the indicators given below for scaled dimension, it is proposed to use the well-known formula (1) [9].

The diameter of the block Δ_i for averaged zones of rock decompression with the formation of stockworks is determined in Ln, L = 4.7–4.8. The indicators for the main North-West stockwork and the Central section "stand out" from the series. In the first case, it is probably possible to state the "duplication" of anomalous zones of fracturing and, accordingly, mineralization. In the second case, from those listed, the "reduction" is also almost twofold, fig. 1.

The average Ln value from 4.5 to 4.9 is noted for the distance between the anomalous fracture zones (morphological cores of mineralization), and the exit beyond these limits of the distances between the fracture zones from the South-East to the East area and further to the Deep Zone with Ln L more than 5.7 can be an indicator of both undeveloped fracture zones in these intervals and erosional shear of the upper horizons of the indicated zones, respectively, expanded mineralization zones – the structure of stockworks in the form of an inverted cone, table 3.

The dimensions of stockworks when assessed using the formula L, m = $\sqrt[3]{L_1 \cdot L_2 \cdot L_3}$ (respectively, the strike, thickness, by dip in m) and the logarithmized dimension indicator Ln (L, m) for averaging in the range from 4.2 to 5.8.

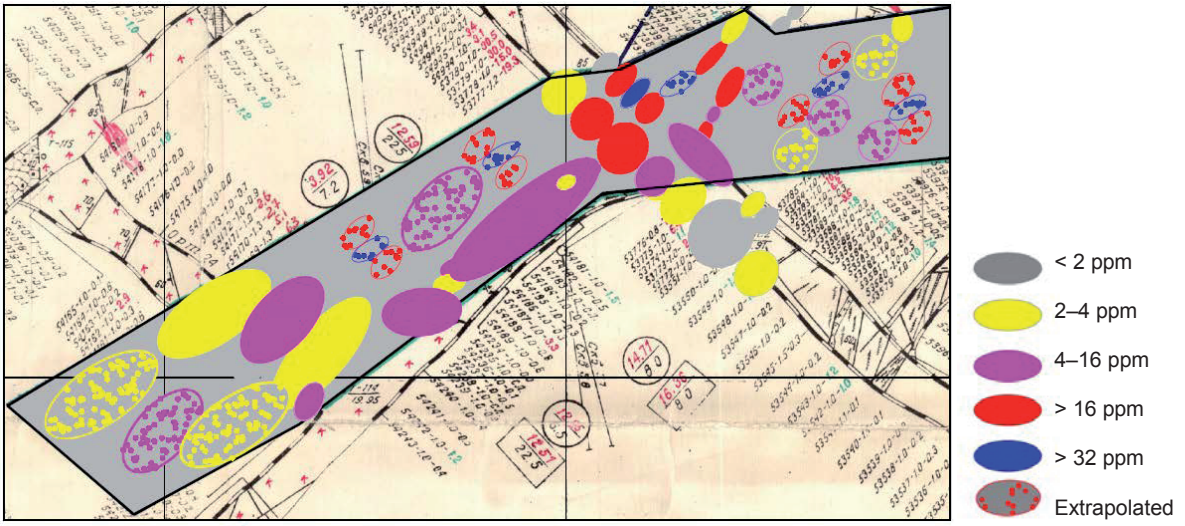

Figure 7. Interpolation of the mosaic discrete structure of mineralization of the fragment of the exploitation block 17-C_1. Colored crappie – classes of gold content
Рисунок 7. Интерполяция мозаичной дискретной структуры оруденения фрагмента эксплуатационного блока 17-C_1. Цветовой крапп – классы содержаний золота

The mosaicity of blocks of the discrete level of the deposit is determined by the distribution and location of stockwork bodies of mineralization and the distance between them, for the discrete level $N \times 1000$, the block of the deposit is determined by the characteristic of practical equality in the discrete subsystem of ore and barren blocks, the mosaicity of the discrete subsystem is expressed in a value close to 42.1% to 57.9%, evaluating the block of the deposit in the general united contour of isolated stockwork bodies, taken as 100%.

Discrete subsystem $N \times 100$ m

Subsystem × 100 m, measured as a set of ore and barren blocks along ten profiles of the exploration model, ore blocks table 4 and barren blocks table 5.

The quantitative ratio of ore blocks to barren blocks is equal in quantity to 90 to 93, the dimension of the exploration model is L =105.5 m (Ln L = 4.7). The total dimension and quantitative distribution of ore and barren blocks in the exploration model contour are given in table 6.

The distribution of ore and barren blocks in the aggregate is 73 to 27%, excluding barren blocks in the contours of ore blocks of transitional mineralization, where ore and barren blocks have approximate equality, which is estimated in the calculated mosaic as 60.2% to 39.8%.

The assessment of the distribution and influence of gold calculated on the basis of the analysis of a sample of 2146 channel samples of ore intersections of two mountain horizons of the adits of the North-West stockwork – Main ore body, are presented in the diagrams of fig. 2, 3. From which it follows that in 55% of the samples (volume of ore contours), more than 93% of gold reserves are concentrated [3, 33].

Thus, in the discrete subsystem of the $N \cdot 100$ m exploration model or stockwork deposit, the mosaic of ore and barren blocks tends to be distributed, respectively, 60 to 40%, in which more than 93% of gold reserves are concentrated in the volume of 55% of ore contours.

Discrete subsystem $N \times 10$ m

This discrete subsystem is geologically distinguished within the exploration model system (× 100 m) in the form of individual ore and barren blocks within exploration profiles (by interpolation of mineralization contours along boreholes, fig. 3; and based on the geotechnological conditions of extraction panels measuring 5 × 5 and 10 × 10 m × 20–40 m (strike), respectively, L, m = 7.9; 15.9 m (Ln L = 2.1 and 2.8), for the purpose of comparability of the dimensions of ore and barren blocks and extraction units [Chuprin, st. 5, 6, abandoned pillars].

Table 7 shows the distribution and influence of gold in a fragment of the reserve contour, block 17-C1 – distinguished under the paradigm of the "continuous" type of mineralization.

From which follows the concentration of more than 98% of gold in the contours of 85% of the sample volume or, accordingly, in the spatial volume of mineralization. The interpretation in the form of a schematic illustration of the discrete type of mineralization is given in fig. 7 in which hypothetically the concentrations of gold by grades of contents are combined into ellipses in proportion to the calculated spatial location of reserves, table 7. To delineate discrete mosaic blocks of mineralization by grades, a form was used for anomalous and ordinary isolations in the horizontal plan in the form of an "ellipse (for three-dimensional space – an ellipsoid with various combinations of longitudinal and transverse axes. An ellipse can quite closely take into account the degree of compactness of the distribution of heterogeneities and elements of anisotropy, areas of their accumulations, the use of geological factors in delineation" [3, 33, 34].

The mosaic nature of the discrete subsystem was obtained by analytical calculations for ten cross-sections of the exploration model; the calculations were made for block-ore (90 blocks), table 8, and barren (93 blocks), table 9.

Thus, the distribution of ore and barren blocks by quantity is 90 ore blocks to 93 barren. The average dimensions of ore to

Table 8. Dimensions of ore blocks by profiles
Таблица 8. Размерности рудных блоков по профилям

Profiles	Dimensions of combined blocks by profile			Degree from exploration model	Dimensionality of single blocks		
	$L_1 \times L_2 \times L_3$	*l*, m	Ln *L*		Number of blocks	*l*, m	Ln *L*
1	23 916,8	28,8	3,4	1,3	11	12,5	2,5
2	42 163,6	34,8	3,5	1,2	11	11,9	2,4
3	43 884,0	35,3	3,6	1,2	17	13,7	2,6
4	58 021,0	38,7	3,7	1,1	29	11,9	2,5
5	49 730,0	36,8	3,6	1,2	23	10,1	2,3
6	25 194,0	29,3	3,4	1,2	22	10,5	2,3
7	60 204,0	39,2	3,7	1,1	21	12,1	2,5
8	33 378,2	32,2	3,5	1,2	13	12,6	2,5
9	10 455,0	21,9	3,1	1,4	10	9,9	2,3
10							
Total:	346 947,0	70,3	4,2		157		
Average	38 549,6	33,8	3,5	1,2		11,7	2,4

Table 9. Calculation of the dimensions of barren blocks of the exploration model by profiles
Таблица 9. Расчет размерности безрудных блоков разведочной модели по профилям

Profile	Dimension of barren intervals, blocks by profiles			Power function of the exploration model	The dimensions of individual barren blocks of the exploration model by profiles			
	$L_1 \times L_2 \times L_3$	*l*, m	Ln *L*		number of blocks in profile	*V*, m³	*L*, m	Ln *L*
1	27 508	30,2	3,4	1,3	3	9169,3	20,9	3,0
2	49 685	36,8	3,6	1,2	12	4140,4	16,1	2,8
3	68 486	40,9	3,7	1,2	10	6848,6	19,0	2,9
4	72 719	41,7	3,7	1,2	17	4277,6	16,2	2,8
5	59 135	39,0	3,7	1,2	12	4928,0	17,0	2,8
6	62 394	39,7	3,7	1,2	13	4799,6	16,9	2,8
7	50 470	37,0	3,6	1,2	13	3882,3	15,7	2,8
8	28 017	30,4	3,4	1,3	7	4002,4	15,9	2,8
9	23 500	28,6	3,4	1,3	6	3916,7	15,8	2,8
10								
Total	441 914	76,2	4,3		93			
Average	49 102	36,6	3,6	1,2			17,1	2,8

barren blocks by profiles are *L*, m (Ln *L*): ore 33.8 m (3.5) to 36.6 (3.6) and by average individual blocks, respectively 11.7 m (2.4) to 17.1 m (2.8). Distribution of ore and barren blocks by dimension *L*, m, table 10.

Distribution of mosaicity and gold concentration in table 11.

The distribution close to 50% of ore and barren blocks with a predominance of dimensions >10 m in 96% of the frequency of occurrence, gold concentration of 92.4% in a volume of 51%, contrasting statistical and sampling allocation of barren blocks is considered as a very promising pattern of mosaic block organization of mineralization for exploration, assessment of reserves and justification and implementation of geotechnology with a significant reduction in the costs of mining operations per volume of barren blocks [35].

Discrete subsystem $N \times 1$m

The discrete subsystem was measured and studied in six exploration wells of profile 2, core sampling of 391 samples, with a conditional limit of 1.46 ppm, tables 12, 13.

The characteristic of mosaicity is the tendency of concentration of more than 93% of gold in 46% of spatial volume of well testing contours of discrete subsystem. With development of more than 40% of barren intervals with dimension > 8 m. With mosaicity measured in the subsystem as 45% ore to 54% ore-free, table 14.

Table 10. Distribution of exploration model block dimensions by dimensions *L*, m
Таблица 10. Распределение размерностей блоков разведочной модели по размерностям *L*, м

Dimension, m	Frequency	Frequency ratio
1–10	4	0,04
10–20	53	0,59
20–30	21	0,23
30–40	8	0,09
40–50	4	0,04
∑	90	1,00

Table 11. Distribution of ore and barren blocks of the exploration model; gold concentration
Таблица 11. Распределение рудных и безрудных блоков разведочной модели; концентрация золота

Parameters	Ore, %	Barren, %
Distribution	51,7	48,3
Influence	92,4	7,6

Table 12. Distribution of gold grades and influence, %
Таблица 12. Распределение классов золота и влияние, %

Average, ppm	Distribution, %	Influence, %
0,54	54,2	7,2
2,09	15,1	7,8
4,44	9,7	10,7
8,84	13,6	29,6
16,58	4,9	19,9
33,59	2,3	19,1
91,10	0,3	5,8

Table 13. Frequency and distribution of barren and unsuitable intervals
Таблица 13. Частота и распределение безрудных и некондиционных интервалов

Interval, m	Frequency	Distribution, %
2–4	8	29,6
4–8	8	29,6
8–16	7	25,9
16–32	4	14,8

Table 14. Characteristic of mosaicity by interval lengths (testing in linear meters), ore and barren, substandard
Таблица 14. Характеристика мозаичности по длинам интервалов (опробования, пог. м), рудные и безрудные, некондиционные

Total, r. m	Ore, r. m	Barren, r. m
443,9	203,45	240,45
Percent	45,80	54,20

Discrete subsystem $N \times 0{,}01$

The smallest subsystem for observations, which is determined by the results of sensor sorting of ores, the studies were carried out fragmentarily [33] on two samples with ordinary and poor gold contents, the general indicators are given in table 14. The XRT (X-ray transmission sorting) method on an outdated installation (2012). New studies by the SBS (Sensor Based Sorting) method [34] of gold-quartz ores similar in mineral composition have gold extraction indicators during studies up to 99.72%.

The study of samples of three ore fractions, according to the output, has indicators of a pattern of increasing ore blocks in the smallest subsystems, fig. 8 [34].

The discrete subsystem by mosaicity is characterized by average indicators of ore and barren blocks in the proportion of 39.9% to 60.1% with a tendency for gold concentration over 99%. The latter is consistent with the fractal pattern by the ratio of the frequency of occurrence of ore blocks with a decrease in the scale of observations, which have an exponential pattern, fig. 9 (constructed according to the data of measuring the fractality of concentration ore formations) [33, 34].

Conclusions and discussions

1. Ore formation of ore fluid input is controlled by fracture zones with formation of stockwork cone-shaped ore bodies with the base turned to the surface. Ore processes are localized and confined to fracture zones with formation of mosaic block structure: mineralization cores by zones of intensive fracturing, mineralization periphery by transitional fracturing zones and barren blocks by zones of low fracturing or shadow zones. Probably, the structural-tectonic history of the deposit block is prerequisite formed by dome-arc kinematics of faults and fracture zones. Distribution of the latter have radially diverging position in the roof of the intrusive body – the system of organization of block mosaic structure of the discrete mineralization system.

2. The blockiness of mineralization of the Jerooy deposit is self-similar in discrete subsystems of fractality. Mosaic blockiness in discrete subsystems of successive hierarchical stages are equivalent and identical. Which possibly indicates a universal natural pattern of formation and development of the block nature of mineralization.

3. The studied discrete subsystems of mosaicism are presented in table 15. The dimensions of ore and barren blocks of mosaicism are practically equal, the distribution is symmetrical, the arrangement is characterized by systematic repeatability.

4. The logarithmic dimensions of the blocks in the subsystem Ln (n)/Ln $(n + 1)$, according to empirical measurements, have a regular relationship of the power coefficient ≈ 1.2.

5. It is obvious that the distribution pattern of mosaic blocks closest to the natural one is expressed in the discrete subsystem $N \times 0.01$ m. The probable pattern, expressed in the tendency of concentration up to 100% of ore substance in minimum volumes of ore blocks, is up to 13–40%. The given pattern can be considered when forecasting the technological assessment of the enrichment potential and extraction of concentrated ore substance (from enriched ore blocks, the enrichment factor is ≈ from 3–6 to 15 for ore substance. Which obviously predetermines the high effi-

Table 15. Separation of ore and barren blocks when studied using the XRT method
Таблица 15. Разделение рудных и безрудных блоков при исследовании методом XRT

Samples, Au content, ppm (sample weight)	Output of mosaic blocks	
	Ore, %	Barren, %
XRT, common ores, 3,90 ppm (1165,9 kg)	39,9	60,1
XRT, poor ores, 0,92 ppm (584,7 kg)	13,8	86,2
XRT, exploitation ore, 2,4 ppm (581.2 kg)	26,8	73,2

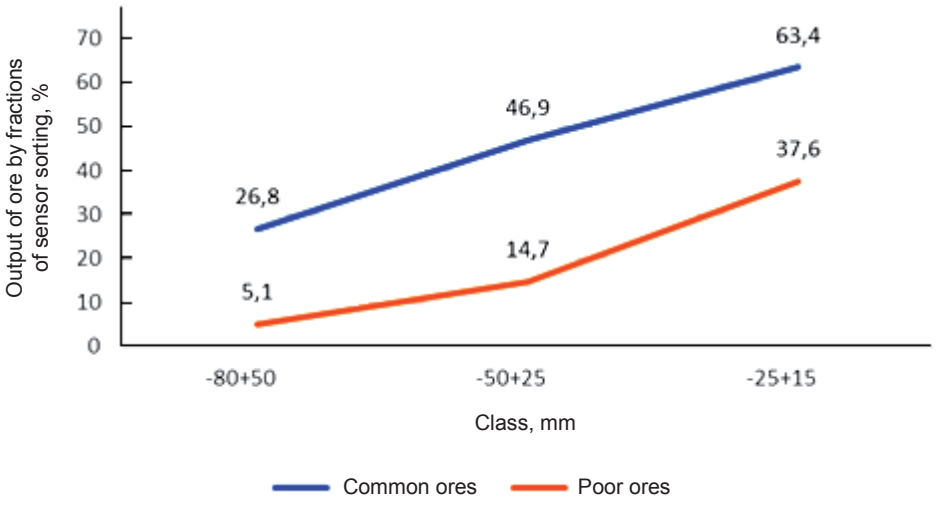

Figure 8. Volume of output of ore blocks by fractions of sensor sorting using XRT separation method
Рисунок 8. Объем выхода рудных блоков по фракциям сенсорной сортировки, метод XRT-сепарации

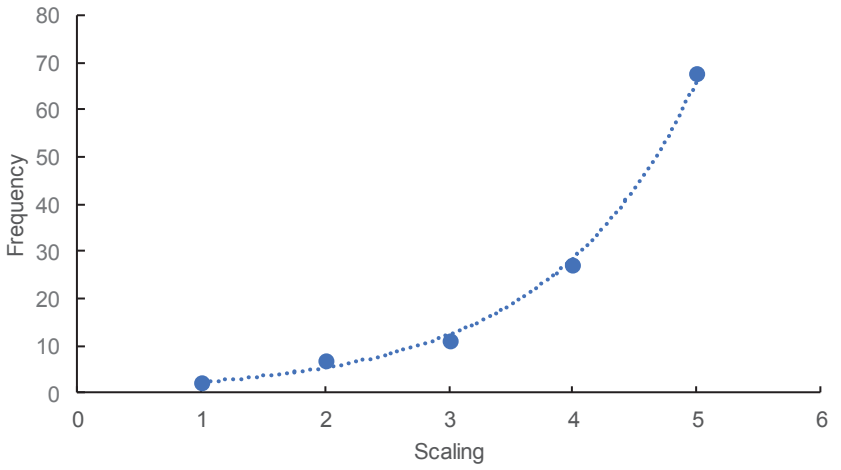

Figure 9. Exponential trend of ore block frequency from scaling (1 – 100 m … 5 – 0.4 m)
Рисунок 9. Экспоненциальный тренд частоты рудных блоков от масштабирования (1 – 100 м … 5 – 0,4 м)

ciency of using modern SBS (Sensor Based Sorting) technologies.

6. Detailed studies of discrete subsystems and block mosaics at the levels of $N \times 100$ m, $N \times 10$ m, $N \times 1$ m allow formulating new approaches and tools for assessing reserves and resources of an ore deposit by the size of the contour, parameters, and mineralization conditions. In particular, the geological and economic assessment has the ability to forecast and implement geotechnical, geotechnological, technological, conditional, and economic indicators of a mining project; exploration methods and forecasting the cost assessment of a deposit.

Table 16. Distribution of mosaic blocks among discrete subsystems
Таблица 16. Распределение мозаичных блоков по дискретным подсистемам

Discrete subsystems, m	Ore blocks, %	Barren blocks, %	Gold concentration, %
$N \times 1000$	42,1	57,9	
$N \times 100$	60,2	28,8	> 93
$N \times 10$	51,7	48,3	92,4
$N \times 1$	45,8	54,2	> 93
$N \times 0{,}01$	39,9	60,1	> 99

REFERENCES

1. Pavlov A. M. 2011, Fractal Properties of the Geological Environment as an Indicator of the Complexity of the Conditions of Exploitation of Gold Ore Deposits. *Gornyy Informatsionno-Analiticheskiy Byulleten'* [Mining Informational and Analytical Bulletin (Scientific and Technical Journal)]. Moscow, no. 6, pp. 60–66. (*In Russ.*)
2. Nikonorov V. V. 2009, Ore Deposits of Kyrgyzstan. Bishkek, 482 p. (*In Russ.*)
3. Satybaldiev L. I., Ryabko I. I., Yarushevsky G. A. [et al.]. 1984, Report on Detailed Exploration of Deep Horizons of the Jerooy Gold Deposit With Calculation of Reserves as of August 1, 1984. (*In Russ.*)
4. Kopp M. L. 2017, Arcuate Extension Structures in Regional and Global Tectonic Settings. *Trudy Geologicheskogo Instituta* [Proceedings of the Geological Institute]. Moscow, 97 p. *(In Russ.*)
5. Kurlenya M. V., Oparin V. N. 2000, Problems of Nonlinear Geomechanics. *Fiziko-Tekhnicheskiye Problemy Razrabotki Poleznykh Iskopayemykh* [Physical and Technical Problems of Mineral Development], no. 4, pp. 3–26. (*In Russ.*) https://elibrary.ru/item.asp?id=14954392
6. Kocharyan G. G. 2016, Geomechanics of Faults. Moscow, 424 p. (*In Russ.*)
7. Kocharyan G. G., Spivak A. A. 2003, Dynamics of Deformation of Block Rock Massifs. Moscow, 423 p. *(In Russ.*)
8. Sadovsky M. A. 1979, Natural Lumpiness of Rock. *Doklady Akademii Nauk SSSR* [Reports of the USSR Academy of Sciences], vol. 247, no. 4, pp. 829–831 (*In Russ.*)
9. Sadovsky M. A., Kocharyan G. G., Rodionov V. N. 1988, On the Mechanics of Block Rock Massif. *Doklady Akademii Nauk SSSR* [Reports of the USSR Academy of Sciences], vol. 302, no. 2, pp. 306–307 *(In Russ.*)
10. Piotrovsky V. V. 1964, Using Morphometry to Study the Relief and Structure of the Earth. *Zemlya vo Vselennoy* [Earth in the Universe]. Moscow, pp. 278–297 (*In Russ.*)
11. Snetkov V. I. 2018, Fractal Analysis as a Key Element of Mineral Deposit Geometrization. *Izvestiya Sibirskogo otdeleniya Sektsii nauk o Zemle RAEN. Geologiya, razvedka i razrabotka mestorozhdeniy poleznykh iskopaemykh* [Proceedings of the Siberian department of the Section of Earth sciences of the Russian Academy of Natural Sciences. Geology, exploration and development of mineral deposits], vol. 41, no. 3, pp. 106–118 (*In Russ.*)
12. Turcotte D. L. 1997, Fractals and Chaos in Geology and Geophysics. Cambridge: Cambridge University Press, 398 p. https://doi.org/10.1017/CBO9781139174695
13. Pirajno F. 2019, Hydrothermal Processes and Mineral Systems. Dordrecht: Springer, vol. 1, 1250 p. https://doi.org/10.1007/978-1-4020-8613-7
14. Filonyuk V. A., Dubovskaya I. A. 2016, On Some Reasons for the Low Efficiency of Geological and Methodological Support for Modern Exploration and Production Technologies in the Gold Mining Industry. *Izvestiya SO sektsii nauk o Zemle RAYEN. Geologiya, poiski i razvedka rudnykh mestorozhdeniy* [News of the Siberian Branch of the Earth Sciences Section of the Russian Academy of Natural Sciences. Geology, Prospecting and Exploration of Ore Deposits], no. 3 (56), pp. 29–43. (*In Russ.*)
15. Ermoshkin D. N., Kurmanaliev K. Z., Mansurov V. A., Mezhelovskiy V. I., Babkin E. A. 2023, Justification of the Use of a Mosaic System of Pillars in Barren Blocks During the Development of Vein Gold Deposits. *Gornaya Promyshlennost'* [Mining Industry], no. 3, pp. 108–114. (*In Russ.*) https://doi.org/10.30686/1609-9192-2023-3-108-114
16. Makarov P. V. 2007, Evolutionary Nature of Block Organization of Geomaterials and Geoenvironments. Universal Criterion of Fractal Divisibility. *Geologiya i Geofizika* [Geology and Geophysics], vol. 48, no. 7, pp. 724–746 (*In Russ.*)
17. Makapov P. V., Kappenko N. I., Cmolin I. Yu., Ctefanov Y. P., Tunda V. A., Xomyakov A. N. 2005, Study of Deformations and Expansions of Geomaterial and Geoproperty, How is an Organized System. *Fizicheckaya Mezomexanika* [Physical Mesomechanics], vol. 8, pp. 17–20. (*In Russ.*)
18. Malinetsky G. G., Potapov A. B. 2002, Modern Problems of Nonlinear Dynamics. Moscow, 356 p. (*In Russ.*)
19. Haken G. 1985, Synergetics. Hierarchy of Instabilities in Self-organizing Systems and Devices. Moscow, 411 p. (*In Russ.*)
20. Kapitsa S. P., Kurdyumov S. P., Malinetsky G. G. 2002, Synergetics and Future Forecasts. Moscow, 342 p. (*In Russ.*)
21. Glendorf P., Prigogine I. 2003, Thermodynamic Theory of Structure, Stability and Fluctuations. Moscow, 280 p. (*In Russ.*)
22. Prigogine I., Nikolis G. 2003, Cognition of the Complex. Introduction. Moscow, 342 p. (*In Russ.*)
23. Akhromeeva T. S. et al. 1992, Non-stationary Structures and Diffusion Chaos. Moscow, 544 p. (*In Russ.*)
24. Mandelbrot B. 2002, Fractal Geometry of Nature. Moscow, 656 p. (*In Russ.*)
25. Balek A. E., Panzhin A. A., Konovalova Yu. P., Melnik D. E. 2018, Features of the Stress State of the Rock Massif of the Sokolovsky Iron Ore Deposit. Innovative Geotechnologies in the Development of Ore and Non-metallic Deposits: Collection of Reports of the 7th Int. Scientific-technical Conference. Ekaterinburg, pp. 256–264. (*In Russ.*)
26. Butakov L. I. et al. 1995, Technology of Development of Gold Ore Deposits. Moscow, 336 p. (*In Russ.*) URL: https://www.geokniga.org/books/9011
27. Ermoshkin D. N., Naszaraliev B. A., Yarovoy N. V., Dzhumanbaev V. V. 2023, Fractality of ore-controlling and ore-localizing faulting zones at Dzhamgyr gold deposit. *Gornyi Zhurnal* [Mining Journal], no. 3, pp. 26–31. https://doi.org/10.17580/gzh.2023.03.03
28. Vasiliev N. Yu., Mostryukov A. O., Petrov V. A., Tveritinova T. Yu., Tveritinov A. Yu. 2020, Parameters of the Direct Connection Between the Processes of Endogenous Ore Formation and Volumetric Loosening of Rocks, Controlled by Tectonic Deformations of the Reverse Type (Based on Reconstructions of Stress Fields of Regional and Local Ranks). Fundamental Problems of Tectonics and Geodynamics. Proceedings of the Lii Tectonic Conference. Moscow, pp. 118–124. (*In Russ.*)
29. Wyborn L. A. I., Heinrich C. A., Jaques A. L. 1994, Australian Proterozoic mineral systems: essential ingredients and mappable criteria. Proceedings of the 1994 AusIMM Annual Conference (Darvin, August 1994). Melbourne: Australian Institute of Mining and Metallurgy, pp. 109–115.
30. Cox S. F. 2005, Coupling between deformation, fluid pressures, and fluid flow in ore-producing hydrothermal systems at depth in the crust. *Economic Geology*, 100th Anniversary Volume, pp. 39–75. https://doi.org/10.5382/AV100.04
31. Sibson R. H., Skott J. 1998, Stress/fault controls on the containment and release of overpressured fluids: Examples from gold-quartz vein systems in Juneau, Alaska; Victoria, Australia and Otago, New Zealand. *Ore Geology Reviews*, vol. 13, issues 1–5, pp. 293–306. https://doi.org/10.1016/S0169-1368(97)00023-1
32. Zhenhao Xu., Tengfei Yu., Peng L., Shucai L. 2023, Anomalous patterns of clay minerals in fault zones. *Engineering Geology*, vol. 325, article number 107279. https://doi.org/10.1016/j.enggeo.2023.107279
33. Kurmanaliev K. Z., Nesipbaev D. A. 2024, Development of the Concept of Geological and Industrial Assessment of Reserves and Resource-saving Technology for the Development of the Underground Mine Jerooy Based on Fractal Analysis Data on the Discrete Form of Mineralization Using the Example of a Local Section of the Mine: Report on Research and Development Work. Bishkek, 212 p. (*In Russ.*)
34. Chuprin K. E., Rakhmatov S. N., Kurmanaliev K. Z. 2025, Fractal Discreteness and Ore Preparation of the Smallest Subsystems of Mineralization by Sensor Sorting. *Izvestiya KGTU* [News of KSTU], no. 1, pp. 114–126. https://doi.org/10.56634/16948335.2025.1.114-126 (*In Russ.*)
35. Chuprin K. E., Kurmanaliev K. Z. 2024, Mosaic Blockiness of Stockwork Mineralization and Justification of Underground Geotechnology of the Djerui Gold Deposit (Kyrgyz Republic). *Nedropol'zovaniye i Transportnyye Sistemy* [Subsoil Use and Transport Systems], vol. 14, no. 4, pp. 21–35. (*In Russ.*) https://doi.org/10.18503/SMTS-2024-14-4-21-35

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Мозаичная блочность дискретных подсистем штокверкового золоторудного оруденения, месторождение Джеруй (Кыргызская Республика)

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Аннотация

Актуальность. Вследствие исчерпания приповерхностных месторождений с богатыми рудами назрела проблема разработки методик разведки и оценки бедных руд для вовлечения в эксплуатацию забалансовых месторождений, исследований на основе парадигмы «дискретного» как перспективного научного направления против используемого в практике «непрерывного» типа оруденения.
Цель – выявление характеристик блочной организации оруденения на основе фрактальности.
Объект исследования – штокверковое золотокварцевое месторождение Джеруй (Кыргызская Республика).
Методология и методика – измерение фрактальности методом ячеек; измерение дискретности иерархических таксонов; мозаичная блочность размерности и распределения блоков ядра, периферии оруденения и безрудных блоков; методики: измерение блоков дискретных подсистем; измерение мозаичности по разведочной модели эксплуатационной разведки фрагмента штокверка размерностью 220 х 80–100 м х 100–180 м, разведочная сеть буровых скважин 20 х 20 м; 66 скважин: > 6000 керновых проб; геостатистический метод, распределение золота, графические и аналитические методы измерения блоков.
Научная гипотеза. Оруденение представлено самоподобной иерархией дискретных подсистем (по размерности *N* х 1000 м; х 100 м; х 10 м; х 0,01 м), состоящих из эквивалентных мозаичных структур в дискретных подсистемах, что является закономерной блочной организацией оруденения.
Результаты, научная новизна. Образование, распределение и размещение блоков (ядра оруденения, переходных зон и безрудных зон) имеют самоподобное тождественное по распределению и распространению блоков в подсистемах – закономерность дискретных подсистем, годных для обоснования новых подходов к методике разведки и оценки золоторудных месторождений.

Ключевые слова: дискретность, мозаичность блоков оруденения, фрактальность, ядро, периферия и безрудные блоки.

ЛИТЕРАТУРА

1. Павлов А. М. Фрактальные свойства геологической среды как показатель сложности условий эксплуатации золоторудных месторождений // ГИАБ. 2011. № 6. С. 60–66.
2. Никоноров В. В. Рудные месторождения Кыргызстана. Бишкек, 2009. 482 с.
3. Сатыбалдиев Л. И., Рябко И. И., Ярушевский Г. А. и др. Отчет по детальной разведке глубоких горизонтов золоторудного месторождения Джеруй с подсчетом запасов по состоянию на 1 августа 1984 г.
4. Копп М. Л. Дугообразные структуры растяжения в региональных и глобальных тектонических обстановках // Труды ГИН РАН. М.: ГЕОС, 2017. Вып. 616. 96 с.
5. Курленя М. В., Опарин В. Н. Проблемы нелинейной геомеханики // ФТПРТИ. 2000. № 4. С. 3–26. https://elibrary.ru/item.asp?id=14954392
6. Кочарян Г. Г. Геомеханика разломов. М.: ГЕОС, 2016. 424 с.
7. Кочарян Г. Г., Спивак А. А. Динамика деформирования блочных массивов горных пород. М.: Академкнига, 2003. 423 с.
8. Садовский М. А. Естественная кусковатость горной породы // Докл. АН СССР, 1979. Т. 247. № 4. С. 829–831.
9. Садовский М. А., Кочарян Г. Г., Родионов В. Н. О механике блочного горного массива // Докл. АН СССР. 1988. Т. 302. № 2. С. 306–307.
10. Пиотровский В. В. Использование морфометрии для изучения рельефа и строения Земли // Земля во Вселенной. М.: Мысль, 1964. С. 278–297.
11. Снетков В. И. Фрактальный анализ – необходимый элемент геометризации месторождений полезных ископаемых // Известия СО Секции наук о Земле РАЕН. Геология, разведка и разработка месторождений полезных ископаемых. 2018. Т. 41. № 3. С. 106–118.
12. Turcotte D. L. Fractals and Chaos in Geology and Geophysics. Cambridge: Cambridge University Press, 1997. 398 p. https://doi.org/10.1017/CBO9781139174695
13. Pirajno F. Hydrothermal Processes and Mineral Systems. Dordrecht: Springer, 2019. Vol. 1. 1250 c. https://doi.org/10.1007/978-1-4020-8613-7
14. Филонюк В. А., Дубовская И. А. О некоторых причинах низкой эффективности геолого-методического обеспечения современных поисково-разведочных и эксплуатационных технологий в золотодобывающей отрасли // Известия СО Секции наук о Земле РАЕН. Геология, поиски и разведка рудных месторождений. 2016. № 3 (56). С. 29–43.

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15. Ермошкин Д. Н., Курманалиев К. З., Мансуров В. А., Межеловский В. И., Бабкин Е. А. Обоснование применимости мозаичной системы целиков в безрудных блоках при отработке жильных месторождений золота // Горная промышленность. 2023. № 3. С. 108–114. https://doi.org/10.30686/1609-9192-2023-3-108-114
16. Макаров П. В. Эволюционная природа блочной организации геоматериалов и геосред. Универсальный критерий фрактальной делимости // Геология и геофизика. 2007. Т. 48. № 7. С. 724–746.
17. Макаров П. В. Об иерархической природе деформации и разрушения твердых тел // Физическая мезомеханика. 2004. Т. 7. № 4. С. 25–34.
18. Малинецкий Г. Г., Потапов А. Б. Современные проблемы нелинейной динамики. М.: УРСС, 2002. 356 с.
19. Хакен Г. Синергетика. Иерархия неустойчивостей в самоорганизующихся системах и устройствах. М.: Мир, 1985. 411 с.
20. Капица С. П., Курдюмов С. П., Малинецкий Г. Г. Синергетика и прогнозы будущего. М.: УРСС, 2002. 342 с.
21. Гленсдорф П., Пригожин И. Термодинамическая теория структуры, устойчивости и флуктуаций. М.: УРСС, 2003. 280 с.
22. Пригожин И., Николис Г. Познание сложного. Введение. М.: УРСС, 2003. 342 с.
23. Нестационарные структуры и диффузионный хаос / Т. С. Ахромеева [и др.]. М.: Наука, 1992. 544 с.
24. Мандельброт Б. Фрактальная геометрия природы. М.: Ин-т компьютерных исследований, 2002. 656 с.
25. Балек А. Е., Панжин А. А., Коновалова Ю. П., Мельник Д. Е. Особенности напряженного состояния горного массива Соколовского железорудного месторождения // Инновационные геотехнологии при разработке рудных и нерудных месторождений: сб. докл. 7-й Междунар. науч.-техн. конф. (Екатеринбург, 10–11 апр. 2018 г.). Екатеринбург: УГГУ, 2018. С. 256–264.
26. Технология разработки золоторудных месторождений / Л. И. Бутаков [и др.]. М.: Недра, 1995. 336 с. URL: https://www.geokniga.org/books/9011
27. Ермошкин Д. Н., Назаралиев Б. А., Яровой Н. В., Джуманбаев В. В. Фрактальность блоков рудолокализующих и рудоконтролирующих сдвиговых зон золоторудного месторождения Джамгыр // Горный журнал. 2023. № 3. С. 26–31. https://doi.org/10.17580/gzh.2023.03.03
28. Васильев Н. Ю., Мострюков А. О., Петров В. А., Тверитинова Т. Ю., Тверитинов А. Ю. Параметры прямой связи между процессами эндогенного рудообразования и объемного разуплотнения горных пород, контролируемой тектоническими деформациями взбросового типа (по реконструкциям полей напряжений регионального и локального рангов) // Фундаментальные проблемы тектоники и геодинамики: материалы LII Тектонич. совещ. М.: ГИН РАН, 2020. С. 118–124.
29. Wyborn L. A. I., Heinrich C. A., Jaques A. L. Australian Proterozoic mineral systems: essential ingredients and mappable criteria // Proceedings of the 1994 AusIMM Annual Conference (Darvin, August 1994). Melbourne: Australian Institute of Mining and Metallurgy, 1994. P. 109–115.
30. Cox S. F. Coupling between deformation, fluid pressures, and fluid flow in ore-producing hydrothermal systems at depth in the crust // Economic Geology. 2005. 100th Anniversary Volume. P. 39–75. https://doi.org/10.5382/AV100.04
31. Sibson R. H., Skott J. Stress/fault controls on the containment and release of overpressured fluids: Examples from gold-quartz vein systems in Juneau, Alaska; Victoria, Australia and Otago, New Zealand // Ore Geology Reviews. 1998. Vol. 13. Issues 1–5. P. 293–306. https://doi.org/10.1016/S0169-1368(97)00023-1
32. Zhenhao Xu., Tengfei Yu., Peng L., Shucai L. Anomalous patterns of clay minerals in fault zones // Engineering Geology. 2023. Vol. 325. Article number 107279. https://doi.org/10.1016/j.enggeo.2023.107279
33. Курманалиев К. З., Несипбаев Д. А. Разработка концепции геолого-промышленной оценки запасов и ресурсосберегающей технологии отработки подземного рудника «Джеруй» на основе данных фрактального анализа о дискретной форме оруденения на примере локального участка рудника: отчет о НИР. Бишкек: Геолэкспертпроект, 2024. 212 с.
34. Чуприн К. Э., Рахматов С. Н., Курманалиев К. З. Фрактальная дискретность и рудная подготовка наименьших подсистем оруденения сенсорной сортировкой // Известия КГТУ. 2025. № 1. С. 114–126. https://doi.org/10.56634/16948335.2025.1.114-126
35. Чуприн К. Э., Курманалиев К. З. Мозаичная блочность штокверкового оруденения и обоснование подземной геотехнологии золоторудного месторождения Джеруй (Кыргызская Республика) // Недропользование и транспортные системы. 2024. Т. 14. № 4. С. 21–35. https://doi.org/10.18503/SMTS-2024-14-4-21-35

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