



Original article

EDN: XLEMXO

DOI: 10.21285/2686-9993-2026-49-3-1

Study of the geomechanical behavior of the rock mass of the Vysokoye-2 ore body

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Abstract. The Vysokoye-2 inclined ore body belongs to the Kindikansky section of the Irokindinsky gold ore deposit and is mined underground in mountainous area. Mining operations are conducted in complex geological conditions, which determine changes in the natural and man-made stress behavior of the rock mass. To ensure effective management of rock pressure, a set of studies was performed including a comprehensive study of the geomechanical behavior of the rock mass at the lower levels of the ore body. As part of the research, the fracturing parameters of the rock mass were refined, physical and mechanical tests of rock samples were conducted, and the stability of rock exposures in mine workings was assessed. In situ measurements using the method of the Ural Branch of the Russian Academy of Sciences (at slot-discharge stations in workings of the lower levels) made it possible to identify the distribution patterns of natural stresses in the rock mass. The stress distribution pattern within the Vysokoe-2 ore body was determined as gravitational-tectonic. To assess the man-made component of the stress behavior, stress calculations around the workings were performed using the finite element method. This work established permissible stress levels for the rocks, as well as formation patterns of destructive stresses along the workings' contours. The analysis showed that man-made stresses exceed the permissible values, and therefore, measures for stress relief of the mass are required in the zone of stable rocks. Data from visual inspection of the condition of the workings indicate the presence of static rock pressure. Taking into account the results obtained, recommendations have been developed for the safe mining operations at the Vysokoe-2 ore body.

Keywords: underground mining, physical and mechanical properties, fracturing, stability, stresses, geomechanics

For citation: Pavlov A.M., Bolotnev A.Yu., Olzoev B.N. Study of the geomechanical behavior of the rock mass of the Vysokoye-2 ore body. *Earth sciences and subsoil use*. 2026;49(?):?-?. DOI: 10.21285/2686-9993-2026-49-3-1.

Научная статья

УДК 622.272:622.274

Исследование геомеханического состояния массива горных пород рудного тела Высокое-2

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Резюме. Наклонное рудное тело Высокое-2 относится к Киндиканскому участку Ирокиндинского золоторудного месторождения и разрабатывается подземным способом в гористой местности. Горные работы ведутся в сложных геологических условиях, определяющих изменение природного и техногенного напряженного состояния массива горных пород. С целью обеспечения эффективного управления горным давлением в ходе проведенных работ выполнен комплекс исследований геомеханического состояния массива горных пород на нижних горизонтах рудного тела. В рамках работ уточнены параметры трещиноватости массива, проведены физико-механические испытания образцов горных пород и оценена устойчивость обнажений в горных выработках. Натурные измерения по методике Уральского отделения Российской академии наук (на станциях щелевой разгрузки в выработках нижних горизонтов) позволили выявить закономерности распределения природных напряжений в массиве горных пород. Характер распределения напряжений в массиве рудного тела Высокое-2 определен как гравитационно-тектонический. Для оценки техногенной составляющей напряженного состояния выполнен расчет напряжений вокруг выработок с использованием метода конечных элементов. В рамках работ установлены допустимые уровни напряжений для пород, а также закономерности формирования разрушающих напряжений вдоль контура выработок. Анализ показал, что техногенные напряжения превышают допустимые значения, вследствие чего в зоне устойчивых пород требуется проведение мероприятий по разгрузке массива. Данные визуального обследования состояния выработок свидетельствуют о наличии статического горного давления. С учетом полученных результатов разработаны рекомендации по безопасному ведению горных работ на рудном теле Высокое-2.

Ключевые слова: подземная разработка, физико-механические свойства, трещиноватость, устойчивость, напряжения, геомеханика

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Для цитирования: Павлов А. М., Болотнев А. Ю., Олзоев Б. Н. Исследование геомеханического состояния массива горных пород рудного тела Высокое-2 // Науки о Земле и недропользование. 2026. Т. 49. № ?. С. ?-?. DOI: 10.21285/2686-9993-2026-49-3-1.

Introduction

The Irokindinsky gold ore deposit is located in the southern spurs of the South Muya Ridge, within the basins of the Tulduń and Tuluya rivers (left tributaries of the Vitim River). Administratively, the deposit is part of the Muisky District of the Republic of Buryatia; the distance to the Baikal-Amur Mainline railway station (the regional center, Taksimo) is 74 km to the south.

The terrain in the area is of a transitional type: the northern part is characterized by high-mountain relief with strong ruggedness, while the southern part is of medium-mountain relief. The elevations of the watersheds range from 1,200 to 2,000 m above sea level. Elevation differences between watersheds and valley floors vary from 300–400 to 1,000 m.

The climate in the region is sharply continental with large daily temperature fluctuations. The deposit is located in a seismically active area with a probable maximum earthquake intensity of 9 points (MSK-64 scale).

The Vysokoye-2 ore body is located within the Kindikansky area of the deposit.

The host rocks are represented by gneisses. The gneisses in the near-contact zone with the ore body are beresitized, with local areas of graphitization zones extending subparallel to the ore body along its upper and lower contacts. In the immediate vicinity of the ore body, the rocks are subjected to intense fracturing. The thickness of the schistosity zones vertically ranges from 0.2 to 3.0 m. The contact between the quartz vein and the schistosity zone is distinct and clear, with the fractures filled with fault gouge.

The ore body is a schistosity zone with quartz veinlets, exhibiting a variable thickness from 0.35 to 0.6 m, averaging 0.4 m, a dip angle from 22 to 40°, and a corrugated surface shape.

The stability of mine workings is reduced due to the presence of schistosity zones and fracturing of the ores and host rocks, as well as the presence of local areas of graphitization zones. Horizons below the 1,160 m level are located in transitional, technogenic, and thawed permafrost zones. The rock mass

of the ore body is characterized predominantly by moderately stable and unstable conditions – with unstable rocks accounting for 30%.

Development of the balance reserves is carried out through two declines, from which crosscuts are driven. These serve to divide the extraction blocks into sublevels with a vertical spacing of 25 m. Ore drifts and raises are used for reserve development; extraction is carried out using a room-and-pillar system with support of the stoped area, employing self-propelled mining equipment.

Mining of the ore body is conducted at a depth of more than 700 m from the surface, which causes changes in the temperature regime and the natural and induced stresses of the rock mass. At the lower levels (absolute elevations in the range of 1,060–1,110 m), manifestations of rock pressure are recorded, expressed as collapses from the sides and roofs of the workings; this factor is accompanied by an increase in the ore dilution rate during extraction.

Given the established mining-geological conditions, constant geomechanical monitoring of the mass condition is required for the correct substantiation of geotechnology parameters. This is precisely why the task of studying the geomechanical behavior of the Vysokoye-2 ore body becomes relevant.

In accordance with the requirements of regulatory documents, specialists from the Irkutsk National Research Technical University (INRTU) in the field of geotechnology and geomechanics of underground ore deposit mining have carried out research work on the geomechanical behavior of the rock mass, considering the development of the lower levels of the Vysokoye-2 ore body at the Kindikansky area of the Irokindinsky deposit. The performed studies have made it possible to formulate a substantiated set of geotechnology parameters regulating the extraction of reserves at the lower horizons of the Vysokoye-2 ore body.

Materials and methods

The research was carried out as part of the technical assignment under Contract No. 0067/25



concluded with LLC “Irokinda” (Ulan-Ude, Russia). The physical and mechanical characteristics of the rocks of the Vysokoye-2 ore body were obtained from testing samples taken at the lower levels. The studies were conducted in the Geomechanics and Rock Physics Laboratory of INRTU in compliance with the applicable Russian standards. These parameters formed the basis for geomechanical calculations used to assess the mass condition in the area of mine workings.

The stability assessment of rock exposures was based on a spatial-statistical analysis of tectonic structures. The analysis was performed using photographic materials of core from exploration boreholes.

The initial natural stresses in the mass were determined by means of in situ measurements at slot-discharge stations in the workings of the lower levels of the ore body, in accordance with the method of the Institute of Mining of the Ural Branch of the Russian Academy of Sciences (UB RAS) [1, 2]. The results of previous similar studies are reflected in works characterizing the natural patterns of stress distribution and their relationship with ore potential, as well as approaches to justifying the parameters for mining ore bodies under complex mining-geological conditions [3–11]. Methods for assessing and determining the stress-strain behavior of the rock mass and methods for predicting rockburst hazard, applicable in the design and conduct of mining operations, were also used [7–11].

To evaluate the stress-strain behavior of the structural elements of the mining system employed, mathematical modelling was carried out using the finite element method [12, 13].

The calculations were performed with the FEM software package (developed by Professor O.V. Zoteev, Institute of Mining, UB RAS) [15–17]. The following initial data were taken into account:

- values of the initial stresses of the rock mass;
- physical and mechanical properties of the rocks (including elastic modulus, Poisson’s ratio, internal friction angle, cohesion, density, compressive and tensile strength, and other parameters);
- geometric characteristics of the mine working network.

The modelling results are presented both in graphical (figures, graphs) and numerical form. The analysis of the stress-strain behavior made it

possible to establish key patterns of rock pressure distribution, in particular in pillars, working walls, and stopes of the undermined mass.

The calculation of induced stresses was carried out using relationships developed by V.F. Trubmachev, G.A. Katkov, D.I. Becker, N.P. Vlokh, A.V. Zubkov, and L.I. Sosnovsky [18]. In this process, stress concentration coefficients were determined separately.

Actual manifestations of rock pressure were studied during an in situ visual inspection of the workings of the Vysokoye-2 ore body. During the inspection, mandatory photographic recording of the condition of the support and the rock mass was carried out, which made it possible to document the characteristic features of their current behavior.

Results and discussion

During the present research, from the lower levels of the Vysokoye-2 vein – from the area where the rock pressure observation stations were installed, at the 1,160 m level – 6 rock samples were taken in the form of core material, represented by interlayered gneisses and beresites.

Based on the results of laboratory tests of the physical and mechanical properties of the rocks, it was found that the samples taken from the Vysokoye-2 vein are characterized by high elastic and strength parameters typical of rocks of magmatic and metamorphic origin.

The following values of physical and mechanical characteristics were determined:

- bulk density – 0.028 MN/m³;
- angle of internal friction – 33°;
- Poisson’s ratio – 0.2;
- elastic modulus – 81 GPa;
- deformation modulus – 70 GPa;
- cohesion – 14 MPa;
- compressive strength – 95 MPa;
- tensile strength – 15 MPa.

Upon water saturation of the samples, no noticeable decrease in strength properties occurs, i.e., the rocks are water-resistant. The Protodyakonov strength coefficient according to M.M. Protodyakonov was obtained in the range of 6–10, which corresponds to rocks of medium strength and strong rocks.

The assessment of rock brittleness using the method of G.N. Kuznetsov (by the ratio of



uniaxial compressive and tensile strengths) at the lower levels of the mine showed that the rock samples presented are prone to brittle failure. The average brittleness coefficient is 6.7, which exceeds the brittleness criterion of G.N. Kuznetsov, equal to 6.

The ratio of elastic to total deformations according to the method of Ya.A. Bich showed a high propensity of the presented samples to brittle failure under load [19].

The laboratories of INRTU and the Research Institute of Mining Geomechanics and Mine Surveying, during tests on samples of analogous lithotypes of rocks and ores taken from the overlying levels, had previously confirmed the propensity of the rocks and ores of the Vysokoye-2 ore body to brittle failure under load. This revealed characteristic is consistent with previously established patterns of mass behavior.

The data from laboratory studies of the strength and elastic properties of rocks conducted in 2012–2025 show good convergence of results. This allows the conclusion that the physical and mechanical characteristics of the rock mass have been stable over the indicated period.

For the calculations, averaged physical and mechanical properties were used as input parameters – they were obtained from the results of laboratory tests on core from ore intervals of exploration boreholes of the Vysokoye-2 ore body. These values are presented in Table 1.

During the analysis of photographic materials of core from 264 exploration boreholes drilled from drill chambers at the 1,110–1,160 m levels, the presence of characteristic discing was recorded in only 16 boreholes, which accounts for less than 6% of the total number of boreholes examined.

An assessment was made of the degree of core discing in exploration boreholes drilled from underground workings. The obtained data allow the conclusion that the rock mass along the Vysokoye-2 vein is characterized by the presence of small-area and thin (0.05–0.5 m thick) zones of gneiss rocks that are in a highly stressed state.

The sections with core discing are located at a considerable distance from the borehole collar, outside the zone of abutment pressure of the workings, which indicates the presence of isolated highly stressed zones in the rock mass associated with tectonic faults or contacts of rocks with different strengths. In the event of exposure of such zones, which are composed of interlayered gneisses with thin lenticular gneisses and breccias, the mass will disintegrate (relieve without dynamic manifestations of rock pressure), while in the case of thicker monolithic interlayers of rocks, rock pressure manifestations in the abutment zone in the form of spalling may occur.

As part of the spatial-statistical analysis of mass fracturing based on photographic materials of core from exploration boreholes, a calculated estimate of the weighted average fracture

Table 1. Calculated physical and mechanical properties of rocks for stress modeling of the rock mass (Vysokoye-2 ore body)

Таблица 1. Расчетные физико-механические характеристики пород для моделирования напряжений массива (рудное тело Высокое-2)

Physical and mechanical property	Value in natural state
Poisson's ratio	0.2
Angle of internal friction, deg.	33
Cohesion, MPa	14
Elastic modulus, GPa	81
Residual strength, MPa	9.7
Protodyakonov strength coefficient (according to Prof. M.M. Protodyakonov scale)	9
Density, t/m ³	2.75
Bulk density, mN/m ³	0.0282
Stability category	Moderately stable, unstable
Deformation modulus in sample, GPa	70
Deformation modulus in mass, GPa	5–12
Fracture frequency, per meter	13
Average size of structural block, m	0.07



intensity (specific fracturing) was performed. The indicator is presented as the number of fractures per 1 linear metre of the core interval. It should be noted that in order to optimize the solution of technological tasks and to analyze the degree of influence of ore veins on the fracturing of the host mass, the fracture intensity was assessed in the vicinity (7–15 m) of the ore bodies, i.e., the future stoping chambers.

The analysis showed that the fracture intensity near the ore bodies and in the rest of the rock mass is practically comparable. Thus, the presence of ore bodies does not lead to a significant increase in the fracturing of the contour mass.

The average statistical fracture intensity in the zone near the ore bodies, calculated from the core analysis data from 13 exploration boreholes (total length of the studied intervals 306 m), is 13.9 ± 1.9 fractures per 1 linear metre. The statistical homogeneity of the results for all boreholes has been confirmed: the data belong to a single sample. At the same time, the average distance between individual fractures varies within the range of 6–8 cm.

In terms of mass volume, the distribution of fracture intensity is as follows: in 68% of the volume, the indicator value does not exceed the average level, while in the remaining 32%, it exceeds it.

Taking into account the obtained results, the rock mass at the lower levels of the deposit has been assigned to the categories of moderately stable and unstable rocks. In order to identify the natural – initial stresses, slot-discharge stations were established at a depth of 620–730 m from the surface along crosscut 1/1060, and drifts 3/1060 and 4/1060 in thawed rocks. The total number of slots made at the stations is 16. The revealed patterns of the initial stress field acting at the lower levels of the Vysokoye-2 ore body, based on measurements at a depth of 620–730 m, showed that at a depth of 700 m from the earth's surface, the maximum stresses in the rock mass of the Vysokoye-2 ore body act horizontally, across the strike of the ore veins. In this direction, the stresses exceed the vertical ones by a factor of 1.6. The horizontal stresses oriented along the strike of the ore veins (longitudinal) are somewhat lower; they exceed the vertical ones by a factor of 1.1. The stress distribution in the rock mass of the

Vysokoye-2 ore body is of a gravitational-tectonic nature.

Such a stress distribution is characteristic of the deep levels of many vein deposits [20].

The predicted values of the initial stresses for the mass of the lower levels (depth 700–950 m) are subject to approximation using the following calculation formulae:

$$\begin{aligned}\sigma_v &= -\gamma H; \\ \sigma_l &= -1.1 \times \gamma H; \\ \sigma_t &= -1.9 \times \gamma H,\end{aligned}$$

where: σ_v – vertical stresses, MPa; σ_l – longitudinal stresses, MPa; σ_t – transverse stresses, MPa; γ – bulk density of rocks, MN/m³; H – measurement depth, m.

The above dependencies are proposed for use as boundary conditions in engineering calculations of induced stresses in the structural elements of mining systems for conducting mining operations under conditions of the thawed rock mass at the lower levels of the Vysokoye-2 ore body at depths of up to 900–950 m from the earth's surface.

The corresponding predicted values of the initial stresses for the lower levels are presented in Table 2.

Extrapolation of the results of in situ measurements performed in 2025 at a depth of 620–730 m is permissible for a range of no more than 200–250 m for geomechanical calculations. Thus, the maximum depth to which extrapolation of the data is justified is 900–950 m from the earth's surface; it is recommended to repeat the measurement cycle of the initial stresses of the rock mass in order to ensure timely prevention of negative rock pressure manifestations in both dynamic and static forms.

To assess the stress-strain state of the structural elements of the mining system employed at the mine, the FEM software package was used. The processing of the calculation data with its help made it possible to determine the key patterns of rock pressure distribution, in particular in pillars, working sidewalls, and stopes of the undermined mass. In addition, based on the modelling, an assessment of the stability of the structural elements of the mining system was performed.

Graphical results of the modelling of the stress-strain behavior for single horizontal and inclined workings (crosscuts, inclined-transport decline) located outside the zone of influence of



Table 2. Predicted values of initial stresses of the lower horizons of the Vysokoye-2 ore body
Таблица 2. Прогнозные значения первоначальных напряжений нижних горизонтов
рудного тела Высокое-2

Depth of mining operations, m	Stress value, MPa		
	vertical	horizontal	
	σ_v	σ_l	σ_t
700	-19.6	-21.6	-31.4
800	-22.4	-24.6	-35.8
900	-25.2	-27.7	-40.3
950	-26.6	-29.3	-42.6

Note. σ_v , σ_l , σ_t – vertical, longitudinal and transverse stresses, respectively, MPa.

stopping operations are presented in Fig. 1. Analysis of the data showed that compressive stresses predominate in these workings. The highest stress values were noted in the roof and in the corner sections of the roof, while the lowest were in the sidewalls of the workings.

At depths of 700–950 m, the stresses in the sidewalls of single workings amount to -10...-13 MPa. This stress level is significantly lower than the permissible values: 76 MPa – according to the criterion of dynamic rock pressure manifestations, and 21 MPa – according to the criterion of static forms of manifestations. Consequently, the sidewalls of the workings are characterized as non-rockburst-hazardous and stable. The stresses in the roof and roof corners at these depths reach -59...-80 MPa, which is practically less than the permissible stresses for dynamic manifestations (down to

depths of 900 m, above which they exceed), but higher than the permissible values for static manifestations of rock pressure. The roof and roof corners of single horizontal and inclined workings are unstable, starting from depths of 600 m.

Thus, single horizontal and inclined workings outside the zone of influence of stopping operations at depths of 600–900 m are in the area of static rock pressure manifestation and require support.

The results of modelling the stress-strain behavior in over-drift and under-drift pillars and in preparatory drifts are presented in Figs 2, 3.

The minimum stress values were recorded in the sidewalls of the ore drifts. At depths of 700–950 m, their magnitude varies in the range from -28 to -38 MPa. This stress level is below the maximum permissible value of 76 MPa (taking into account

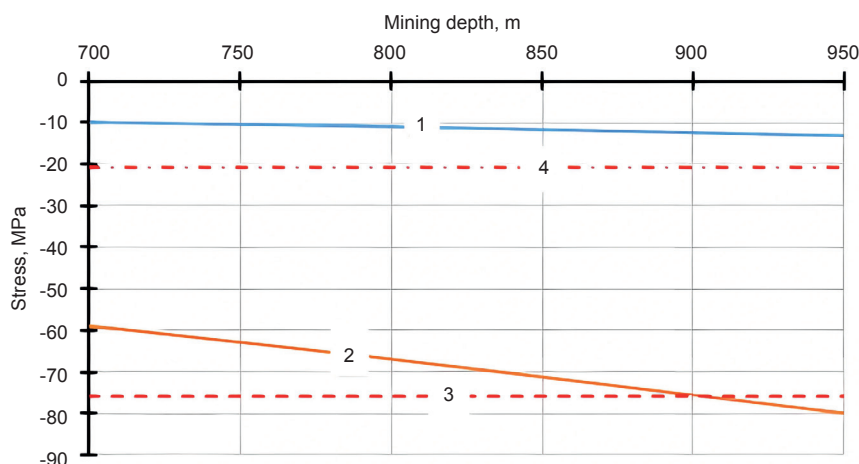


Fig. 1. Stresses at the contour of single workings outside the influence zone of stopping operations:

- 1 – stresses in the walls; 2 – stresses in the roof and roof corners;
- 3 – stresses permissible for rock pressure manifestations in dynamic forms;
- 4 – stresses permissible for rock pressure manifestations in static forms

Рис. 1. Напряжения на контуре одиночных выработок вне зоны влияния очистных работ:

- 1 – напряжения в стенках; 2 – напряжения в кровле и углах кровли;
- 3 – напряжения, допустимые по проявлениям горного давления в динамических формах;
- 4 – напряжения, допустимые по проявлениям горного давления в статических формах

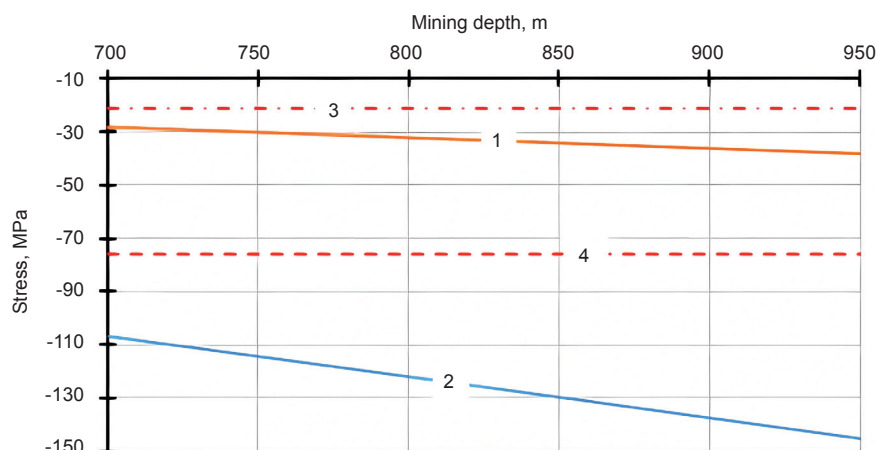


Fig. 2. Stresses at the ore drift contour:

- 1 – stresses in the walls; 2 – stresses in the roof and roof corners;
3 – stresses permissible for rock pressure manifestations in static forms;
4 – stresses permissible for rock pressure manifestations in dynamic forms

Рис. 2. Напряжения на контуре рудных штреков:

- 1 – напряжения в стенках; 2 – напряжения в кровле и углах кровли;
3 – напряжения, допустимые по проявлениям горного давления в статических формах;
4 – напряжения, допустимые по проявлениям горного давления в динамических формах

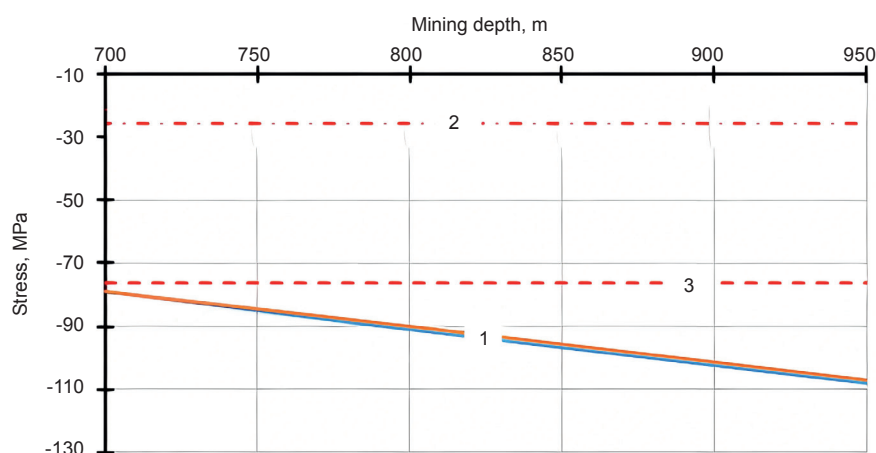


Fig. 3. Stresses in protective over-drift and under-drift pillars:

- 1 – stresses in under-drift and over-drift pillars;
2 – stresses permissible for rock pressure manifestations in static forms;
3 – stresses permissible for rock pressure manifestations in dynamic forms

Рис. 3. Напряжения в предохранительных надштрековом и подштрековом целиках:

- 1 – напряжения в подштрековом и надштрековом целиках;
2 – напряжения, допустимые по проявлениям горного давления в статических формах;
3 – напряжения, допустимые по проявлениям горного давления в динамических формах

possible dynamic rock pressure manifestations), but exceeds the normative value of 21 MPa established for long-term service workings under static forms of rock pressure manifestation. At the same time, the stresses in the roof of the ore drifts are quite high and exceed the permissible values for both static and dynamic manifestations at all analyzed depths (see Fig. 2). The sides and roof of the ore drifts at great depths require support. Obviously, during the extraction of a block, the

high stresses in the protective pillars of the ore drift should be compensated by intra-block pillars and protective pillars of the raise. However, during the process of extracting most of the pillars in the block, the destruction of the protective pillars of the ore drifts is quite likely, including in dynamic forms. It is recommended to develop technical measures for strengthening or reducing stress concentration in the protective pillars of the self-propelled ore drifts.



The stress results in the roof of the stope prior to the extraction of intra-block pillars are presented in Fig. 4.

The stresses in the roof of the stope are lower than the permissible stresses for rock pressure manifestations in both static and dynamic forms. In the roof of the stopes at the time of formation of all intra-block pillars, the stresses, being compressive in nature, are small in magnitude. The roof of the stopes at the time of their formation (with a span of 3 m) is stable when supported with props.

During the visual inspection of the mine workings, manifestations of static rock pressure were recorded at the underlying levels – in the zone of thawed, moderately stable and unstable rocks. This is expressed in spalling of rocks along natural fractures. This phenomenon is observed in cases where there is no support or where it does not correspond to the mining-geological conditions, as well as when the permissible stress values at the working contour are exceeded.

The visual inspection showed that the stability condition of rock mass exposures during the driving of mine workings and the conduct of stoping operations in the blocks is consistent with the conclusions of the conducted studies of the geomechanical behavior of the rocks of the Vysokoye-2 ore body.

Conclusion

The results of the studies on the geomechanical behavior of the rock mass of the Vysokoye-2 ore body allow the following conclusions to be drawn.

Within the framework of the chamber-and-pillar mining system with support and localization of the mined-out area (applied in the extraction of the Vysokoye-2 vein at the Kindikansky area), the greatest hazard in terms of dynamic rock pressure manifestations is posed by the temporary protective (safety) pillars of the block raises and ore drifts. According to the mining development plans, such pillars are left in place for a period of at least three years.

At the time of formation of all intra-block pillars and protective pillars of the raise, the pillars are under conditions of static rock pressure manifestation. The roof of the stopes at the time of their formation (with a pillar spacing of 3 m) requires support (due to fracturing) and is not prone to dynamic collapse. During the extraction of pillars, when the roof span reaches 12–14 m, dynamic rock pressure manifestations may occur in the remaining pillars, while collapses in the roof of the mined-out area between them may occur under the action of high tensile stresses.

The minimum calculated depth for dynamic rock pressure manifestations, without taking into

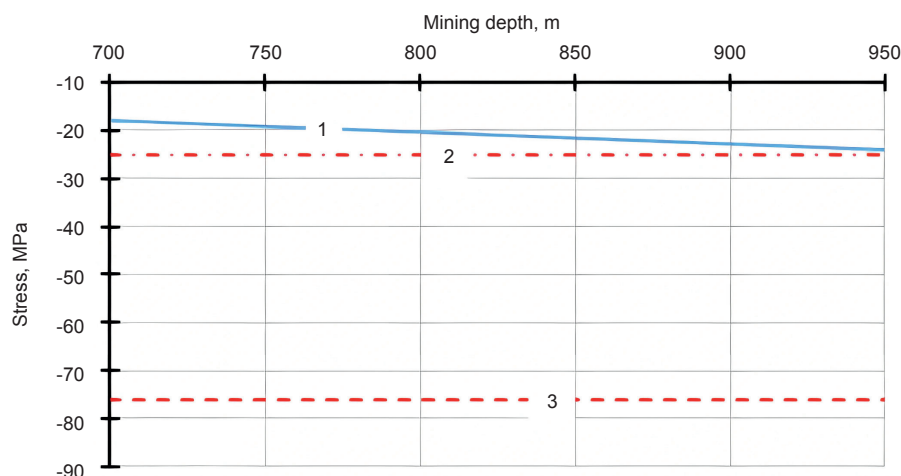


Fig. 4. Stresses in the roof of stoping chambers before the removal of intra-block pillars:

1 – stresses in pillars;

2 – stresses permissible for rock pressure manifestations in static forms;

3 – stresses permissible for rock pressure manifestations in dynamic forms

Рис. 4. Напряжения в кровле очистных камер до погашения внутриблоковых целиков:

1 – напряжения в целиках,

2 – напряжения, допустимые по проявлениям горного давления в статических формах;

3 – напряжения, допустимые по проявлениям горного давления в динамических формах



account temporary pillars, will be 900 m, provided that localization – i.e., timely extraction of the mined-out area during the removal of intra-block pillars – is carried out.

The nature of rock pressure manifestations at depths beyond the calculated critical values directly depends on the physical and mechanical properties of the rocks.

In rocks with high stability, significant elastic and strength parameters, and a predisposition to brittle failure under load, the development of dynamic forms of rock pressure cannot be excluded.

Conversely, in unstable and moderately stable rocks, as well as in those that do not exhibit a propensity for brittle failure, rock pressure manifests in static form and does not pose a risk of rock bursts, including at depths exceeding the calculated critical level.

Based on the results of the geomechanical study of the rock mass of the Vysokoye-2 ore body, the design parameters of the applied mining system were determined and issued, allowing

mining operations to be conducted safely with lower costs.

The mine field of the Vysokoye-2 ore body is characterized by a complex geomechanical setting. This necessitates regular and continuous monitoring by the mining supervisory service. The control should cover both the current state of the rock mass and the compliance of mining operations with the design solutions at the underlying levels, with mandatory consideration of the previously formulated recommendations.

For the timely identification of zones of increased rock pressure and the development of measures for the safe conduct of mining operations in the area of adverse influence within the boundaries of these zones, it is necessary to conduct geomechanical monitoring. When opening up lower, deeper levels and expanding the flanks of existing horizons, it is necessary to continue the study of the rock mass behavior by a specialized organization, especially when introducing new geotechnology parameters.

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Conflict of interests / Конфликт интересов

The authors declare no conflict of interests.

Авторы заявляют об отсутствии конфликта интересов.

The final manuscript has been read and approved by all the co-authors.

Все авторы прочитали и одобрили окончательный вариант рукописи.

Information about the article / Информация о статье

The article was submitted 10.07.2026; approved after reviewing 22.07.2026; accepted for publication 29.07.2026.

Статья поступила в редакцию 10.07.2026; одобрена после рецензирования 22.07.2026; принята к публикации 29.07.2026.