MINING

TECHNOLOGICAL SOLUTIONS DEVELOPMENT FOR MINING
ADJACENT ROCK MASS AND PIT RESERVES TAKING INTO ACCOUNT
GEOMECHANICAL ASSESSMENT OF THE DEPOSIT

Purpose. The assessment of options for opening and mining the upper tier of Oleniy Ruchey apatite-nepheline deposits and technological solutions development taking into account geomechanical calculations of open pit slopes and benches stability, both on the marginal contour and when changing the design values of the slope parameters, open pit benches and the stability safety factor to establish the marginal maximum accepted under the condition of the values stability.

Methodology. Searching for technological solutions of mining is based on the method of mining and geometric analysis of the deposit upper tier, comparison, generalization, systematization, analytical calculations, 3D parametric modeling, three-dimensional numerical modeling of stress-strain state and the rock mass stability by the finite element method.

Findings. According to the research results, the optimal development of mining operations has been proposed for an option providing for the minimum overburden ratio. The parameters of the highwall slopes and their elements on the marginal contour and the development of the deposit are recommended according to the option that provides the maximum possible involvement in the development of the adjacent rock mass and pit reserves mining within the existing limits of the open pit mining tap.

Originality. It consists in feasibility evaluation of using a rational technology for the development of mining operations according to the option that provides for the minimum overburden ratio and possible mining development schemes for mining open pit reserves with an assessment of the possibility of internal dumping during the development of an open pit.

Practical value. The calculations show that for the conditions of a lying side, the normative factor of the slope stability on the marginal contour can be ensured only if they are bank slopes worked along the weakening surfaces, whose cutting should not be permitted.

Keywords: edge, slope, adjacent rock mass, pit reserves, open pit reserves, stress-strain state, stability, development system.
the efficiency of development and completeness of extraction during the mining of ore deposits [1, 2].

Searching, selecting and justifying the options for the development of newly discovered ore bodies, which are both in the adjacent rock mass zone and in the pit reserves with the combined method of their development, ensuring their effective and safe development with the greatest completeness of extraction is an urgent task at present.

The scope of research dealing with the final extraction of reserves located in the marginal zone necessitates their expansion in order to develop a regulatory framework and documents for the design of rational development systems and stripping schemes for adjacent rock mass and sub­career reserves. Today there are no methodologies for selecting the design of development systems for adjacent rock mass and pit reserves by the open, underground or combined way; a rational procedure for developing such reserves has not been substantiated.

The limited development of adjacent rock mass and pit reserves is closely related to geomechanical conditions. Changing the stress­strain state (SSS) of the massif during mining operations in the adjacent rock mass zone leads to changing the position of the sliding surface. On the other hand, the final extraction of reserves in the specified zone begins after the slope has been put into the final position. Consequently, when selecting a technology for final extraction of reserves, geomechanics becomes paramount.

The adjacent rock mass reserves, which are subject to both open and underground final extraction, located beyond the marginal contour of the open­pit mine, are characterized by a more complex geological structure, the presence of isolated sections, and dispersal of reserves along the perimeter of the open pit. The areas of the field that are subject to underground final extraction are, as a rule, confined to lenses, zones of tectonic disturbances, deposits with a low content. The mined ore zones are often represented by local ore deposits, areas with inconsistent thickness, with small sizes of strike and dip, low quality, and sometimes related to off­balance reserves.

When designing the technology for final extraction of adjacent rock mass and pit reserves, the greatest difficulties arise because their development causes a violation of stability of both the pit slopes and benches.

**Methods.** When performing a detailed mining and geometric analysis of the upper tier of the deposit, the volumes of ore and overburden outside the open­pit project contour have been calculated using the method of parallel sections. The essence of the method consists in splitting the deposit with vertical sections (cuts), the distance between which is from 20 m to 80 m. To calculate the reserves, the mineral deposit has been divided into separate calculating blocks, the boundaries of which have been flat sections. At the same time, the total volume of ore amounted to 3,840 thousand m³, including pit ore reserves of 2,756 thousand m³ and adjacent rock mass reserves of 1,084 thousand m³.

**Options of mining operations development schemes with final extraction of reserves.** Possible development schemes of mining in the final extraction of pit reserves have been analyzed. There have been considered and studied possible options of schemes of opening and final extraction of reserves in the adjacent rock mass zone with observance of the conditions for the development of mining operations within the boundaries of the mining allotment. Technological solutions for developing adjacent rock mass and pit reserves are presented in Table 1.

For each of the options presented, in order to select a rational option for mining, there have been determined overburden volumes, horizons of ore divided into pit and adjacent rock mass ores, as well as overburden ratio for comparison with the overburden boundary coefficient, determined from the condition of the equal cost of ore mining by underground and open methods (Table 2).

Analyzing the obtained values of total ore volumes divided into the pit and adjacent rock mass reserves (Table 2), we conclude that the final extraction of reserves under option 1 makes 44 % of the total reserves, including 33 % of the pit and 72 % of adjacent rock mass reserves; under option 2 it is 23 % of the

| Rational options of mining operations development | Advantages | Drawbacks |
|---------------------------------------------------|------------|-----------|
| **No** | **General characteristic of possible schemes of stripping and final extraction of adjacent rock mass and pit reserves** | **Advantages** | **Drawbacks** |
| 1 | **Option 1** | It provides the maximum possible involvement in the development of adjacent rock mass and pit reserves within the existing boundaries of the mining allotment from the condition of providing an access from the surface to the lowest horizon | As a result of the studies, it has been revealed that it is possible to descend as far as possible in the north-eastern and south-western parts of the deposit with open pit mining, and to aximize the ore reserves development in the adjacent rock mass zone | To ensure the given production, it is necessary to remove the entire volume of excavated overburden and to lay it in external dumps |
| 2 | **Option 2** | It provides the maximum possible, as in option 1, involvement in the development of adjacent rock mass reserves and part of the pit reserves of ore bodies traced in the south-western part of the mine field with the depth of 15–45 m | As a result of the studies, the following has been revealed: 1. It is possible to pick up adjacent rock mass ore reserves traced in the laying side of the ore deposit as far as possible. 2. From the pit reserves in mining there are involved only ore bodies with deepening the project boundaries in this part of the mine field to 15–45 m. 3. In the north-eastern part of the mine field its technical boundary does not change along the bottom and along the western slope | To ensure the given production, the entire volume of rock overburden being removed can be laid in the internal dump that can be formed in the north-eastern part of the mine field, whose deepening is not stipulated by the option |
| 3 | **Option 3** | It provides the development of adjacent rock mass and a part of the pit reserves in the south-western part of the mine field, which are also to be opened, as in option 2, and in the north-east part, the pit reserves are mined with the open pit deepening | To ensure the given production, the excavated overburden rocks are to be laid partly in the developed space with filling its southern and northern ends up to the hor. +240 and partly to the external dump | |
total reserves, including 3% of the pit and 72% of adjacent rock mass ores; in option 3 it is 27%, including 9% of the pit and 72% of the adjacent rock mass reserves. It follows that under option 1, it is possible to maximally involve adjacent rock mass and pit reserves in the mining within the existing boundaries of the mining allotment of the open-pit. On the other hand, mining options have a limiting overburden ratio that is adopted equal to 12 m³/m³ for the conditions of mining of this nepheline-apatite ore deposit.

As it can be seen from Table 2, following the analysis of the three considered possible options for opening and preparing schemes of the adjacent rock mass and pit reserves at the Oleńyi Ruchey deposit, it can be concluded that the most rational is option 3, in which the overburden ratio is 8.2 m³/m³ (Table 2), but with a smaller share of production reserves in the adjacent rock mass zone.

**Justification of rational scheme of stripping and preparing procedure.** According to the conditions of the terrain in the open pit, the upland part is marked up to 315 m and the deep part is below 315 m. According to the decisions made during implementation of option 3, it has been proposed to strip the open-floor horizons of the open pit with semi-trenches and the deep part in the south-east side of the open pit with the system of permanent cross-overs. It is rational to produce the reserves located in the adjacent rock mass zone in the following order:

1. The first stage. Developing the maximum possible volume of the adjacent rock mass reserves with 15 m deepening. The duration of the stage will be 2 years of exploitation of the open pit. In parallel, it is necessary to carry out operations related to the construction of a mine for the development of the pit reserves.

2. The second stage. The operations having been completed, the mine is put into operation and the pit reserves are finally extracted by the underground method.

**Geomechanical assessment of slopes and their elements stability accepted in the working project.** When designing the technology of excavation of adjacent rock mass and pit reserves, the greatest difficulties arise because their development causes a violation of stability of both the pit benches and the slope.

The strength characteristics of the rocks of the Oleńyi Ruchey apatite-nepheline deposit obtained by geologists when testing the samples are given in Table 3. The calculated strength characteristics of the rock massif are presented in Table 4, which presents characteristics of rocks, both in the weathering zone and below it.

### Table 2

| Name | Overburden volumes, thousand m³ | Overburden ratio, m³/m³ | Total horizons ore volumes, thousand m³ | Including |
|------|--------------------------------|------------------------|----------------------------------------|-----------|
|      |                                |                        |                                        | Pit reserves | Adjacent rock mass reserves |
| Option 1 | 29650                          | 17.3                   | 1710                                   | 922        | 788                       |
| Option 2 | 7800                           | 8.9                    | 880                                    | 92         | 788                       |
| Option 3 | 8550                           | 8.2                    | 1039                                   | 251        | 788                       |

### Table 3

**Strength characteristics of the rocks**

| Rock               | Ultimate strength, MPa | Brittleness ratio, un. | Internal friction angle, degree | Cohesion in the sample Cₛ, MPA | Hardness ratio, un. |
|--------------------|------------------------|------------------------|-------------------------------|--------------------------------|---------------------|
|                    | compression tension jₛ / at 0.5σₛ₀₀₀ |                          |                               |                                | M. Protodyakonov    | L. Baron            |
| Ristschorrits      | 204                    | 7.4                    | 28                             | 69                             | 41                  | 19.9               | 20                 | 9                  |
| Ristschorrits-juvits| 98                    | 3.9                    | 25                             | 68                             | 40                  | 10.4               | 10                 | 6                  |
| Juvits             | 199                    | 7.4                    | 27                             | 68                             | 41                  | 19.7               | 20                 | 9                  |
| Juvits, leucocratic| 110                   | 6.0                    | 18                             | 64                             | 39                  | 13.7               | 11                 | 7                  |
| Urtites            | 111                    | 4.5                    | 25                             | 67                             | 40                  | 11.3               | 11                 | 6                  |
| Monchiquites       | 276                    | 16.6                   | 17                             | 62                             | 39                  | 34.7               | 28                 | 13                 |

### Table 4

**Calculated strength characteristics of the rock massif**

| Rock lithotypes | Volume weight, t/m³ | Cohesion in the sample, t/m² | Structural weakening ratio | Cohesion, t/m² | Internal friction angle, degree |
|-----------------|---------------------|-------------------------------|--------------------------|---------------|--------------------------------|
|                 |                     |                               |                          |               | Taking into account stability factor | Taking into account stability safety factor |
|                 |                     |                               |                          |               | 1.0 | 1.3 | 1.5 | 1.0 | 1.3 | 1.5 |

**Primary rocks**

|                      |                     |                               |                          |               | 1.0 | 1.3 | 1.5 | 1.0 | 1.3 | 1.5 |
|----------------------|---------------------|-------------------------------|--------------------------|---------------|-----|-----|-----|-----|-----|-----|
| Ristschorrits        | 2.76                | 2028                          | 0.0163/0.0420            | 33.0/85.1     | 25.3/65.4 | 22.0/56.7 | 41  | 33.7 | 30.0 |
| Ristschorrits-juvits | 2.70                | 1061                          |                           | 17.3/44.5     | 13.3/34.2 | 11.53/29.6 | 40  | 32.8 | 29.2 |
| Juvits               | 2.70                | 2008                          |                           | 32.7/84.3     | 25.1/64.8 | 21.8/56.2 | 41  | 33.7 | 30.0 |
| Urtites             | 2.66                | 1151                          |                           | 18.7/48.3     | 14.3/37.1 | 12.4/32.2 | 40  | 32.8 | 29.2 |

**Strength characteristics on the weakening surfaces**

|                      |                     |                               |                          |               | 10  | 7.6  | 6.6  | 25  | 19.7 | 17.2 |

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The magnitude of seismicity is determined by the corresponding schematic maps of SNiP II-7-81*. For the conditions of the area of the deposit, the seismicity coefficient is taken as \( m = 0.025 \) (7 points) [8, 9].

**Results of calculating parameters of slope and bench stability on marginal contour.** The main criterion for assessing the working slope and bench stability is the observance of the equilibrium condition of shearing and confining forces [9], or the excess of the confining forces over the shearing forces acting on the most stressed surface in the adjacent rock mass massif.

In assessing stability of slopes and their elements on the marginal contour, the stability safety factor should, in accordance with the recommendations of the current regulatory documentation [9], be:

- not less than \( \eta = 1.3 \) for the slopes of the open pit;
- not less than \( \eta = 1.5 \) for benches composed of fractured rocks, with the standing period up to 5 years and at least \( \eta = 2.0 \) for benches with the standing period more than 5 years.

The calculation of stability of the slopes has been performed in accordance with the “Guidelines...”. The calculation of stability for determining the parameters of the slopes in the absence of unfavorably oriented surfaces of weakening have been performed by the method of algebraic addition of forces according to the V scheme [9]. The calculations have used the calculated strength properties of rocks of the adjacent rock mass massifs (Table 4). The sliding surface is adopted as smooth and curvilinear, close in shape to circular-cylindrical.

The results of the checking calculations of the stability safety factor \( \eta \) of the slopes on the marginal contour are given in Table 5, taking into account the stability safety factor \( \eta = 1.3 \). The parameters of the slopes are valid in the absence of weakening surfaces in the adjacent rock mass massif. In the presence of weakening surfaces with a fall in the working, it is necessary to roll back strictly along these surfaces.

The results of the checking calculations of the stability safety of the slopes on the marginal contour, corresponding to the design solutions along the profile lines 29 and 33 are given in Table 6. The calculations are valid under the condition that there are no weakening surfaces in the adjacent rock mass massifs, in the presence of weakening surfaces with a fall in the working, the slopes are to be rolled back along these surfaces.

The checking calculations of the slope stability on the design marginal contour and those in option 3 (Table 6) show that their stability is mainly provided by the normative factor of stability safety (\( \eta = 1.3 \)), with the exception of the northwest side sections in the hanging wall (gray).

**Calculating overburden bench slope stability.** There have been calculated overburden benches in weathered and unweathered rocks of the hanging walls, as well as those in weathered and unweathered rocks of the lying side, taking into account the complicating factors, namely the surface weakening, the water content, seismicity and in their absence.

As it is seen from Table 7, according to the calculations, the overburden bench stability with a standard stability factor \( \eta = 1.5 \), taking into account the seismicity of the region and the groundwater level:

- **a) is ensured with the following design parameters:**
  - in weathered rocks for hanging wall benches (in the absence of weakening surfaces in the adjacent rock mass massif) \( H = 30 \text{ m, } \alpha = 60^\circ \) (Fig. 1);
  - in unweathered rocks for hanging wall benches (in the absence of weakening surfaces in the adjacent rock mass massif) \( H = 30 \text{ m, } \alpha = 70^\circ \) (Fig. 2);
  - **b) is not ensured when the angles of overburden benches become steeper:**
    - in weathered rocks for hanging wall benches (in the absence of weakening surfaces in the adjacent rock mass massif) \( H = 45 \text{ m, } \alpha = 55^\circ \) (the parameters of tripled benches on the marginal contour) (Fig. 3);
    - in unweathered rocks for hanging wall benches (in the absence of weakening surfaces in the adjacent rock mass massif) \( H = 45 \text{ m, } \alpha = 65^\circ \) (Fig. 4, a) at \( H = 30 \text{ m and } \alpha = 90^\circ \) (Fig. 4, b) (the parameters of the tripled benches on the marginal contour);
  - **c) is not ensured:**
    - in weathered and unweathered hanging walls.

After analyzing the results obtained from Table 7, comparing with the standard value \( \eta \), we have established the following:

1. A detailed study of the geomechanical situation in the rock massif of the hanging wall, without taking into account the complicating factors, with high probability can indicate a stable position of the benches on the marginal contour with their design values, but taking into account the complicating factors, the change in design values leads to decreasing the stability safety below the standard value [10].

2. Increasing the design slope angles of the bench with its height of 30 m in the hanging wall rocks to 80–90° in the zone

| Slope height \( H \), m | 50  | 100 | 150 | 200 | 250 | 300 | 350 |
|------------------------|-----|-----|-----|-----|-----|-----|-----|
| Angle of the slope inclination \( \alpha \), deg. | 54  | 50  | 50  | 49  | 49  | 48  | 45  |

**Table 5**

| Slope orientation | Pr. L. 29 | Pr. L. 33 |
|-------------------|-----------|-----------|
| NW | SE | NW | SE |
| Slope height, m | 328 | 282 | 165 | 43 | 283 | 207 | 58 | 323 | 301 | 60 | 11 | 87 | 199 | 57 |
| Slope inclination, degree | 41 | 50 | 53 | 75 | 37 | 42 | 65 | 44 | 49 | 78 | 43 | 38 | 36 | 59 |
| Sliding surface | S1 | S2 | S3 | S4 | S1 | S2 | S3 | S1 | S2 | S3 | S1 | S2 | S3 | S4 |
| Stability safety factor | >1.5 | >1.5 | >1.5 | 1.31 | >1.5 | >1.5 | 1.38 | >1.5 | 1.51 | 1.26 | >1.5 | >1.5 | >1.5 | >1.5 |
| Stability safety factor considering seismicity of the region | >1.5 | 1.49 | >1.5 | 1.27 | >1.5 | >1.5 | 1.33 | >1.5 | 1.44 | 1.22 | >1.5 | >1.5 | >1.5 | 1.46 |
| Stability safety factor considering the ground water level | 1.48 | 1.39 | 1.37 | – | >1.5 | >1.5 | – | 1.45 | 1.37 | – | – | >1.5 | >1.5 | 1.5 |
| Stability safety factor considering seismicity of the region and the ground water level | 1.41 | 1.33 | 1.30 | – | >1.5 | >1.5 | – | 1.38 | 1.31 | – | – | >1.5 | >1.5 | – |

**Table 6**

**Summary table of calculating the slope stability safety factor**
ated with the presence of the Main Fault. It should be noted that the indicators of the stability factor of the benches with design parameters of 30 m $\times$ 60° in the lying side do not meet the regulatory requirements [11, 12].

4. Loss of stability safety is also observed when using benches with the following parameters (height $\times$ angle of inclination): 30 m $\times$ 70°, 30 m $\times$ 80°, 45 m $\times$ 65° and 45 m $\times$ 80° in unweathered rocks, the stability factor is higher than in weathered rocks but its value does not correspond to the normative one. A significant loss of stability of rocks indicates the risks of ensuring the mining production safety.

**Conclusions.** There are considered possible options for refining the underground and near-shore reserves of the Oleniy Ruchey deposit under the conditions of mining development within the mining allotment. The performed mining-geometric analysis of the considered options shows that option 3 is the most rational with the lowest overburden ratio satisfying the condition of equality of the ore mining cost of by underground and open methods, and equal to 12 m$^3$/m$^3$.

The purpose of the subsoil user in the modern world is to reduce costs by reducing the volume of overburden operations, of damped jointing leads to a sharp decrease in the stability safety factor (to $\eta = 1.19$), which increases the risk of unsafe mining, including the location of people and mechanisms under such benches.

3. Loss of stability and violation of the integrity of the entire slope, as calculations show, are manifested with the use of doubled and tripled benches when setting the slope into the final position, with the following parameters (height $\times$ angle of inclination) 30 m $\times$ 70°, 30 m $\times$ 80°, 45 m $\times$ 55° and 45 m $\times$ 80° in the weathered lying rocks, which may also be associated with the presence of the Main Fault. It should be noted that the indicators of the stability factor of the benches with design parameters of 30 m $\times$ 60° in the lying side do not meet the regulatory requirements [11, 12].

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**Conclusions.** There are considered possible options for refining the underground and near-shore reserves of the Oleniy Ruchey deposit under the conditions of mining development within the mining allotment. The performed mining-geometric analysis of the considered options shows that option 3 is the most rational with the lowest overburden ratio satisfying the condition of equality of the ore mining cost of by underground and open methods, and equal to 12 m$^3$/m$^3$.

The purpose of the subsoil user in the modern world is to reduce costs by reducing the volume of overburden operations,
which can be achieved by stepping up the angles of sides of slopes and benches. In order to ensure the board safety, to increase the level of mining operations safety in highly fractured rocks and with the presence of the Main Fault, where the lying side carries the entire transport system, the authors have carried out a number of calculations and constructions that indicate an unacceptable increase in the height of the bench to 45 m and its slope more than 55° for weathered and unweathered species, respectively, when setting the board to the final position. At this it is also not allowed to increase the slopes of benches by more than 60° and 70° for weathered and unweathered species, respectively, which is confirmed by geomechanical calculations. The studies have been carried out within the research work, economic contract № 73-646 dated 01/06/2017.

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Розробка технологічних рішень відпрацювання прибортових і підкар’єрних запасів з урахуванням геомеханічної оцінки родовища

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Мета. Оцінка варіантів розкриття й відпрацювання запасів верхнього ярусу апатит-ніфелінового родовища «Оленічний струмок» та розроблення технологічних рішень з урахуванням проведених геомеханічних розра­хунків стійкості уступів і бортів як на гранічному контурі, так і при зміні проектних значень параметрів уступів, борту кар’єра та коефіцієнта запасу стійкості для встановлення їх гранічних, максимально допустимих за умо­вами стійкості, значень.

Методика. Пошук технологічних рішень відпрацювання запасов с зазначення на методі гірничо-геометричного ана­лізу верхнього ярусу родовища, порівняння, узагальнен­ня, систематизації, аналітичних розрахунків, 3-D пара­метричного моделювання, тривимірного числового моделювання напружене-деформованого стану та стій­кості масиву гірських порід методом скінчених елемен­тів.

Результати. За результатами досліджень запропоно­вано оптимальний розвиток гірських робіт за варіантом, що передбачає мінімальний коефіцієнт розкриву. Реко­мендовані параметри узкосі бортів кар’єра та їх елементів на гранічному контурі й відпрацювання родовища за варіантом, що передбачає максимально можливе залучен­ня до відпрацювання прибортових і підкар’єрних запасів в існуючих кордонах гірського відводу кар’єра.

Наукова новизна. Полягає в обґрунтуванні застосо­вання раціональної техніки розвитку гірських робіт за варіантом, що передбачає мінімальний коефіцієнт розкриву, а також можливіх схем розвитку гірських робіт при відпрацюванні прикар’єрних запасів з оцінкою можли­вості внутрішнього отvuставлення при доопрацюванні кар’єрі.

Практична значимість. Проведені розрахунки показа­ли, що для умов лежачого борту нормативний коефіцієнт запасу стійкості уступів на гранічному контурі може бути забезпечений тильки в тому випадку, якщо вони за­точуються за поверхнями ослаблення, підтримання яких недоуміє.

Ключові слова: борт, уступ, прибортові, підкар’єрні, прикар’єрні запаси, наружене-деформований стан, стій­кість, система розробки

Разработка технологических решений отработки прибортовых и подкарьерных запасов с учетом геомеханической оценки месторождения

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Цель. Оцінка варіантів вскрытия і отримання запасів верхнього яруса апатит-нефелінового місцевості «Олений ручей» і розробка технологічних рішення з урахуванням проведених геомеханічних розрахунків устойчивості уступів та бортів як на фіксованому контурі, так і при зміні проектних значень параметрів уступів, борта кар'єра і коефіцієнта запасу устойчивості для установки їх меж бідних, максимально допустимих по умовам устойчивості, значень.

Методика. Пошук технологічних рішення охочого розвитку оснований на методі горно-геометричного аналізу верхнього яруса місцевості, порівняння, обобщення, систематизації, аналітичних розрахунках, 3-D параметричного моделювання, трьохмірного числового моделювання напружено-деформованого стану і устойчивості масиву горних порід методом кінцевих елементів.

Результати. По результатам досліджень виготовлено оптимальне розвиток горних робіт по варіанту, що враховує мінімальний коефіцієнт вскрыши. Рекомендовані параметри откосів бортів кар'єра і їх елементів на фіксованому контурі і отримання месторождения по варіанту, що ураховує мінімальний коефіцієнт вскрыши.

Наукова новизна. Заключається в обоснованні прийняття рациональної технології розвитку горних робіт по варіанту, що враховує мінімальний коефіцієнт вскрыши, а також можливих схем розвитку горних робіт при отриманні прикар'єрних запасів с оцінкою можливості внутрішнього отвалообразування при діяльності кар'єра.

Практична значимість. Проведені розрахунки показали, що для умов лежачого борта нормативний коефіцієнт запасу устойчивості уступів на фіксованому контурі може бути забезпечений лише в тому випадку, коли вони заоткашуються по поверхням погашення, дотримання яких недопустимо.

Ключові слова: борт, уступ, прибортові, подкар'єрні, прикар'єрні, запаси, напружено-деформоване становище, устойчивость, система разработки

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