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THE INFLUENCE OF TECHNOGENIC FACTORS ON THE EFFECTIVE COMBINED DEVELOPMENT OF ORE DEPOSITS

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The predominant field of application of the complex open-underground method is extended steep-falling deposits with a homogeneous nature of mineralization. The main factors influencing the choice of a specific technological scheme are the capacity of the deposit, the value of the ore and the stability of the array. The complexity of solving geomechanical problems determines the main factors of choosing an open-underground technology - the state of the treatment space and the way to control the state of the array.

Keywords: combined geotechnology, technogenic space, mountain range, deformation, geomechanical processes.

РУДАЛЫҚ КЕН ОРЫНДАРЫН ТИІМДІ АРАЛАС ИГЕРУГЕ ТЕХНОГЕНДІК ФАКТОРЛАРДЫҢ ӘСЕРІ

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Күрделі ашық жерасты әдісін қолданудың басым саласы біркелкі минералдану үлгісімен созылған тік шөгінді кен орындары болып табылады. Нақты технологиялық схеманы таңдауға әсер ететін негізгі факторларға кен орнының қалыңдығы, кеннің құндылығы және массивтің тұрақтылығы жатады. Геомеханикалық есептерді шешудің күрделілігі ашық жер асты технологиясын таңдаудың негізгі факторларын анықтайды - өндіріс аймағының жағдайы және массивтің күйін басқару әдісі.

Түйін сөздер: аралас геотехнология, техногендік кеңістік, тау-кен массиві, деформация, геомеханикалық процестер.

ВЛИЯНИЕ ТЕХНОГЕННЫХ ФАКТОРОВ НА ЭФФЕКТИВНУЮ КОМБИНИРОВАННУЮ РАЗРАБОТКУ РУДНЫХ МЕСТОРОЖДЕНИЙ

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Преимущественная область применения комплексного открыто-подземного способа - протяженные крутопадающие месторождения с однородным характером оруденения. Основными факторами, влияющими на выбор конкретной технологической схемы, являются мощность залежи, ценность руды и устойчивость массива. Сложность решения геомеханических задач определяет основные факторы выбора открыто-подземной технологии - состояние очистного пространства и способ управления состоянием массива.

Ключевые слова: комбинированная геотехнология, техногенное пространство, горный массив, деформация, геомеханические процессы.

Introduction. A characteristic feature of the combined development is the presence of quarry and underground treatment spaces located in the immediate vicinity. The combination of open-pit and underground operations or the transition from open-pit mining to the underground method highlights the geomechanical aspects of the choice of technological schemes and development parameters. This is due to the need for joint assessments of the state of the mountain range near underground workings and the side-worked sides of the quarry. The presence of a technogenic space formed by an open mining method significantly complicates the geomechanical situation in the zone of underground work, changing the stress-strain state of elements of underground mining systems, creating zones of concentration and stress relief. On the other hand, the presence of extensive underground mined-out spaces leads to the softening and destruction of the rocks of the overlying massif, reducing the stability of the sides of the quarries, supporting and dividing pillars. Forecasting the behavior of the rock massifs being worked on, assessing the stability of outcrops, determining rational technological parameters of development in this case can be based only on the study of geomechanical processes occurring in the zone of mutual influence of underground and open-pit works. Prerequisites for the successful solution of the problems of combined development, ensuring its effectiveness is achieved by knowing the patterns of distribution of stresses, deformations, displacements formed in the array during the operation of the field in a combined way. Research in these areas is a methodological basis for substantiating the parameters of combined technologies, such as rational opening and preparation schemes, reliable methods for managing the state of the arrays being worked on [1].

Carrying out underground mining operations in the zone of influence of the quarry (under the bottom and in the sides) causes a redistribution of stresses in the developed array. The change in the stress state of the rock mass causes, in turn, the redistribution of values and the direction of action of the shifting and holding forces.

The degree of softening of rocks as a result of mining can be different and depends on the specific conditions of the deposit: the intensity of structural fragmentation of the massif; orientation of the weakening planes relative to underground treatment workings and quarry elements; the initial strength of the massif; the stage of development of the zone of displacement of the degree of mining of the massif; the speed of mining, etc [2].

The influence of the technogenic space formed by the quarry on underground mining operations was also studied in order to determine the preferred order and direction of mining development in the transition zone of the deposit. Variants of the direction of development of underground works from the massif to the slope and from the slope to the array were investigated. The direction of development of underground mining vertically does not have a significant impact on the formation of stress fields in the underworked board. In order to intensify the work and ensure the stability of the sides, on the first underground horizon at the base of the quarry, it is preferable to develop reserves with division into panels, continuous excavation of reserves.

The factors determining the use of open-underground technology in the fields are: the joint use of mine workings for transportation and drainage; the most complete development of the reserves of the deposit; the use of waste rocks as a laying material with a simplified scheme of feeding them into the mine. The factors limiting the use of this method are disadvantages: the need to reduce the seismic impact of quarry and underground explosions on the quarry massif; difficult conditions for ventilation of mine workings.

Materials and methods. The open-underground mining of deposits is characterized by a number of features that determine the conditions of mining operations [3].

First, under the influence of underground work, rock movements and subsidence of the surface are likely. One of the conditions for choosing underground mining systems during joint work is the need for permanent and temporary preservation of the stability of the array. The choice of the development system depends on the specific mining and geological conditions and the possibility of providing a reliable guarantee of work safety.

Secondly, the mutual influence of blasting operations in a quarry and in an underground mine introduces restrictions and should be taken into account when drawing up plans, calculating BVR passports.

The third is that the joint technology of conducting underground and open-pit work requires special organization of labor at quarry ore outlets underground and at drainage works.

Fourth, the high responsibility and complexity of solving geomechanical tasks imply: calculation of the parameters of safe berms between open and underground works; assessment of the thickness of the ceiling over individual sections of the worked-out space; calculation of the parameters of the supporting pillars and the strength of the hardening bookmark; determination of the permissible area of horizontal exposure of the roof of the cleaning space; assessment of the stability of the sides of the quarry being worked by underground workings.

Currently, in most methods of assessing the stability of slopes, only the matching stresses due to the action of gravitational forces are taken into account, and the maximum height of the slope is found by solving the equation of equilibrium of holding and shifting forces along the selected sliding surface in the vertical plane. The value of the stability coefficient of the side depends on the presence of natural tectonic forces in the rock mass, the ratio of the elastic characteristics of the rocks composing the mountain range, the ratio of the geometric dimensions of the quarry.

This leads to great economic damage and aggravation of the environmental situation in the regions of developed mining production.

Further development of the open method of development, especially in the central and southern regions of the country, will be associated with the continuation of the seizure of valuable land. Simultaneously with the increase in the depth of quarries, there is a progressive increase in the volume of stripping and the cost of ore extraction.

An important direction in the development of mineral extraction, which allows to reduce the influence of these negative factors and increase the efficiency of mining operations, is the integrated development of mineral resources. One of the ways to implement this direction is the most effective combination (complex) of various technologies and techniques during the operation of the field.

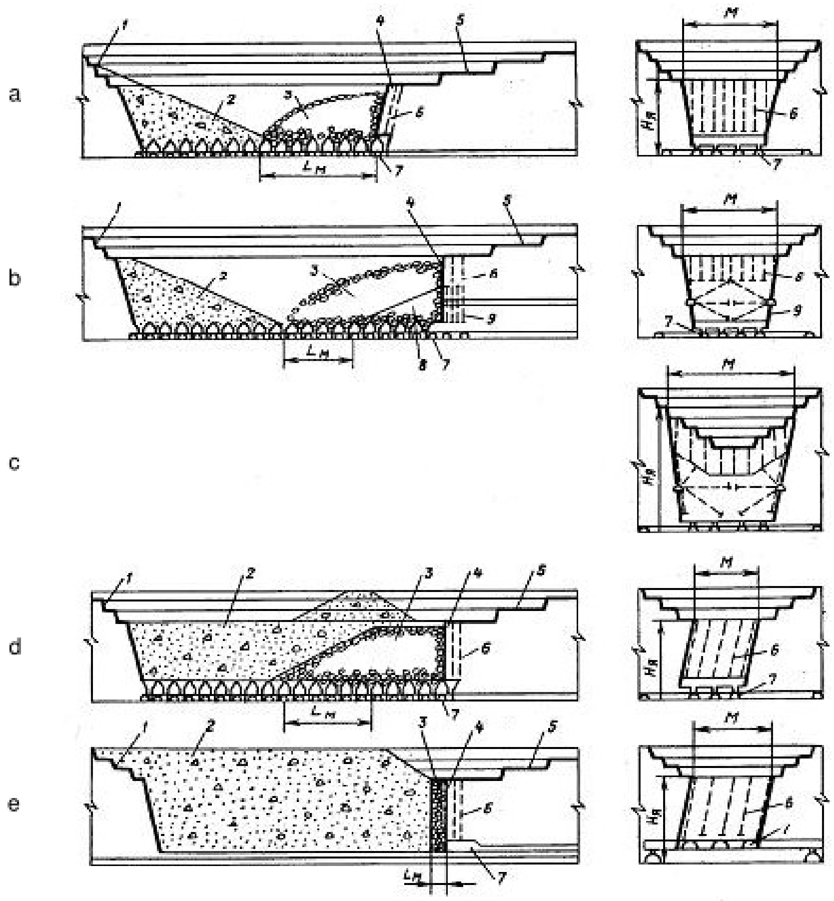
With this method, when open-pit mining reaches the final design depth (Figure 1 a) on one of the flanks of the deposit, they continue to develop horizontally towards the center of the deposit. After the working side of the quarry moves 150-200 m, in the immediate vicinity of the end part of the non-working side, a rising one passes, which connects the bottom of the quarry with the pre-designed workings of the underground horizon. With a series of vertical wells, the rising is expanded into a cut-off slot located across the stretch of the ore body at its full capacity. The underlying stratum (open-underground tier) is drilled to the full height from the bottom of the quarry and collapsed following the advance of the front of the open works with the subsequent issuance of ore mass through underground workings. Reserves of deeper horizons are worked out underground by a floor-chamber system or a system of floor forced collapse. Thus, a single developed space of a quarry, an open-underground tier and underground mining is created. It is used as a container for placing internal dumps, which, by ensuring the loading of the sides of the developed space, increase their stability.

At newly developed deposits, it is possible to open the ore horizons of the quarry with a complex of underground workings, which are also used in the development of the open-underground tier. Due to this, the non-working side is freed from transport communications for its use in the formation of internal dumps.

The complex open-underground method is also applicable in existing quarries, where the implementation of planned production volumes is constrained by the backlog of stripping operations and the lack of space for the placement of external dumps. In this case, the design boundaries of the quarry can be revised and favorable conditions for an earlier transition to underground mining can be provided [4].

The technology in question has a number of features that determine its effectiveness and application prospects. They determined the main directions of research.

Geomechanical processes in the combination of open and underground mining operations in general, and in the complex open-underground method in particular, are characterized by significant heterogeneity of stresses and deformations due to the imposition of several stress fields on the same section of the massif due to the complicated configuration of a single developed space. The stability of the ledge for the basic variant (Fig. 1a) was studied by the finite element method in relation to the conditions of the Prioskolsky deposit of the Kursk Magnetic Anomaly (KMA). The analysis showed that the weakest structural element is the cutting zone. The stability of a ledge with a height of 100 m with a slope angle of 70 ° can be provided with a margin factor of 1.5 with the ratio of the area of the pillars in the cutting zone to its total area of at least 0.4. The stability of the ledge of a higher height is achieved by the exclusion of advanced cutting and the formation of exhaust workings with a lag, under the bulk of the collapsed ore mass. In this case, a feature of the stress-strain state is the formation of a zone of concentration of compressive stresses in the lower part of the ledge and a zone of tensile stresses under the bottom of the developed space (Figure 1).



a - without loading the sides and ledge with rock mass; b - with partial loading of the ledge with broken rock; c - with the completion of deep horizons in an open way without additional separation of the sides of the quarry; d, e - with full loading of the ledge and sides of the worked space, respectively, with bottom and end ore release; 1 - non-working side of the quarry; 2 - internal dump; 3 - ore mass; 4 - ledge of the open-underground tier; 5 - working side of the quarry; 6 - parallel descending wells; 7 - output workings; 8 - loading of the ledge; 9 - fan wells

Figure 1 - Principal variants of an integrated open-underground method development

With an increase in the height of the open-underground tier and a decrease in the width of the upper working area, the zone of concentration of compressive stresses expands, and the stresses themselves increase, at the same time, the zone of tensile stresses is removed from the ledge. Drilling and exhaust workings outside the lower part of the ledge and loading a high ledge with a collapsing rock mass can reduce the concentration of stresses in the selected zones.

On the basis of the bulk medium model, an analysis of the stability of the vertical ledge was carried out [5-6]. It has been established that the stability of an undisturbed vertical ledge composed of quartzites is ensured when the beaten ore is loaded, located at the angle of the natural slope of its entire surface, with the exception of the upper part, at a height equal to the depth of the vertical crack of separation. Studies carried out by the laboratory of Rock Pressure Problems of the IPKON RAN on the example of the Annovsky deposit have shown that the loading of a high ledge ensures its stability even in the presence of unfavorably oriented cracks in the array. In contrast to the periodically (once every 1-2 months) collapsed ledge, the stability of the sides of the developed space must be ensured during the entire life of the transition zone.

The study of stress fields in the sides of the open-underground tier for the conditions of the Annovsky deposit was carried out using the polarization-optical method. It is established that at the height of the tier 100-120 m, the stability of the unloaded sides of the developed space is achieved at their slope angle of no more than 70°. The dependence of the safe slope angles of the ab sides (degree) on the height of the open-underground tier, taking into account the strength of the K_k rocks, can be represented as

$$a_\delta = \text{arcctg}K_k \cdot H_я \quad (1)$$

The flattening of the sides of the worked-out space as the depth of the worked-out space increases leads to the fact that the width of its bottom gradually decreases. At the maximum height of the tier, the section of the developed space takes the shape of a triangle (Figure 2). This height H_{max} (m) depends on the thickness of the deposit M

$$H_{\max} = \sqrt{\frac{M}{2K_k}} \quad (2)$$

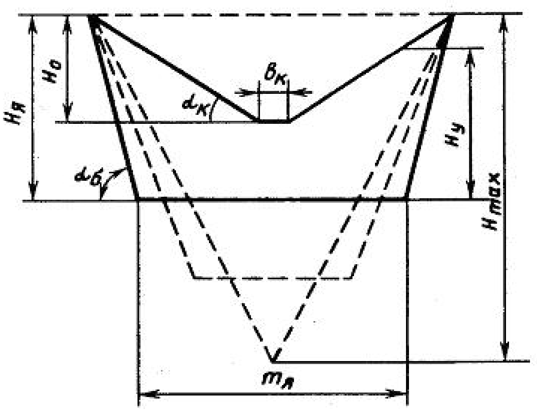


Рис. 1 - Figure 2 - Change in the cross-section of the developed space with options involving the flattening of its sides with an increase in the height of the tier

H_y - the height of the open-underground tier; H_o - the depth of the completion of reserves in an open way without spreading the sides of the quarry; $\alpha_к$ - the angle of the slope of the sides of the quarry during completion; $B_к$ - the width of the bottom of the quarry; α_b - the angle of the slope of the sides of the worked-out space of the open-underground tier; $m_я$ - the width of the bottom of the worked-out space; H_{max} - the maximum possible height of the open-underground tier

The maximum cross-sectional area of the developed space and, accordingly, the largest volume of reserves in the open-underground tier corresponds to its height equal to 0.8 H_{max}.

The necessary stability of the developed space in the period between the end of ore release and the beginning of internal dumping is provided by the choice of a safe angle of slope of the sides, which requires the abandonment of ore triangles; their volume increases with the height of the open-underground tier and the decrease in the angle of incidence of the ore body.

Reduction of ore losses in triangles can be achieved by constant and complete loading of the sides of the worked-out space with rock mass. The possibilities of controlling the stability of the array in this case were considered using numerical modeling of its stress-strain state by the finite element method on the example of the Tarynnakh iron ore deposit. It is established that the factors that have the greatest impact on the stability of the hanging side are the height of the open-underground tier and the angle of incidence of the ore body. Stability is maintained at an angle from 60 to 90° and a tier height of about 80-100 m. At the same time, the zones of possible local destruction and cracking are located in the lower part of the side of the quarry from the hanging side and in its upper part from the recumbent side. However, the presence of such zones does not violate the stability of the system as a whole.

Results and discussion. The results of the assessment of the geomechanical state of the massif made it possible to form three main options for complex open-underground mining, differing in the way of ensuring the stability of the ledge and the sides of the developed space.

The first option provides for the complete release of ore after each cycle of stripping, leaving only a small ore cushion (Figure 3, a). The stability of the ledge and the sides of the worked-out space, which are in an unloaded state for a certain time, is ensured by giving them safe slope angles. The inner dump is formed with a lag from the ledge without contact of the waste rock with the ore mass. At the same time, free bottom release of ore is carried out over the entire area occupied by the recaptured ore. This option, according to geomechanical conditions, ensures the creation of an open-underground tier with a maximum height of 80-100 m using quarry machines for drilling with the formation of only a lower cut without an underground drilling horizon. It is advisable to use it at a deposit capacity of no more than 130-150 m, when the height of the tier will be at least 0.8 H_{max}.

In the second variant, after each breakout cycle, a part of the beaten ore is stored in contact with the ledge, and the internal rock dump is formed similarly to the first variant. In this case, the stability of the ledge of the open-underground tier is ensured by priming it with beaten ore, and the stability of the sides of the worked-out space is provided by giving them a safe angle of slope.

The full release of ore is carried out only outside the loading, within the boundaries of which only 10-15% of the volumes are extracted to create the necessary loosening. Depending on the size of the loading, the height of the ledge under geomechanical conditions can be increased to 150-170 m, which makes it necessary to form an underground drilling horizon above the bottom level outside the stress concentration zone and conduct exhaust workings under the bulk of the beaten ore. This option provides the maximum cross-sectional area of the developed space with a deposit capacity of up to 200-250 m. With higher power, modifications can be used that provide for the completion of the upper part of the open-underground tier reserves in an open way without additional side spacing (Figure 3, c).

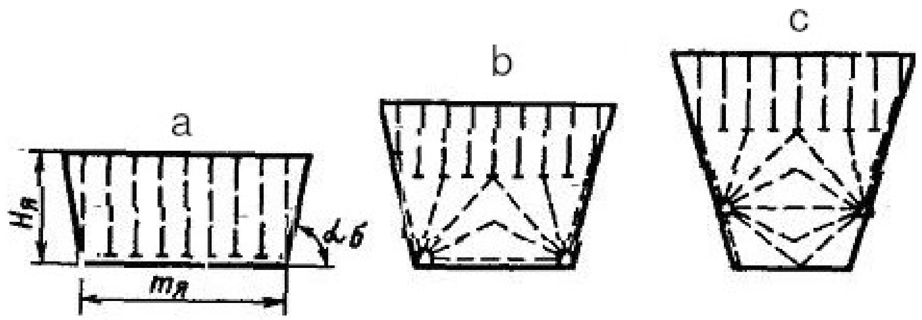


Figure 3 - Schematic diagrams of the opening of the ledge of the open-underground tier

The conditions of free ore release characteristic of the considered options allow increasing the distance between the bottom outlet workings to 15-20 m, which ensures an increase in reserves per outlet to 150-200 thousand tons.

The third option involves the constant filling of the entire worked-out space with rock mass. This is due to the need to break off the entire ledge on the clamping medium and makes it possible to use both an area and an end outlet (Figure 1 d, e). The height of the tier is limited to 70-90 m both according to the conditions of stability of the hanging side, and based on the possibilities of rebounding in a clamped environment. In case of areal release, after each breakout cycle, an internal dump is built up with the placement of rock above the ore mass; ore release is carried out at some distance from the ledge where the dump has reached the design height. At the end outlet, after each breakout cycle, a complete extraction of the ore mass is carried out with vertical contact with the rocks of the inner dump. The use of options with constant filling of the entire worked-out space with rock mass is advisable when the deposit capacity is up to 80-100 m.

The effectiveness of complex open-underground mining largely depends on the reasonable choice of parameters and indicators of drilling and blasting operations.

In principle, three main schemes for the construction of a high ledge are possible (Figure 4). The first scheme (Figure 3, a) provides for drilling the entire ledge with parallel descending wells using quarry machines. This makes it possible to abandon the creation of an underground drilling horizon, but requires the formation of a lower cut. Based on the characteristics of the most powerful quarry equipment, the height of the tier in this case does not exceed 70-90 m, taking into account the cutting.

The second scheme (Figure 3, b) assumes the formation of an underground drilling horizon at the level of the release horizon and the rebounding of the lower part of the ledge with fan wells. The maximum height of the tier in this case can reach 120-140 m.

The disadvantages of the location of drilling workings in the stress concentration zone make the third scheme more promising (Figure 3, c), which provides for drilling horizon above the bottom level and drilling of the lower part of the ledge with ascending and descending fan wells. In this case, the parameters of the existing drilling equipment allow increasing the height of the tier to 160-170 m.

The main feature of the rebound in open-underground mining is the significant depth of blast wells, with the growth of which their deviation from the design position increases. As a result, the consumption of explosives in certain parts of the exploding array becomes less than the calculated one, which leads to a deterioration in the quality of crushing.

Based on data on well deviations at a number of domestic and foreign enterprises and taking into account experience in reducing these deviations, the dependences of the oversized yield on the height of the open-underground tier were calculated and it was found that with the appropriate parameters of drilling and blasting operations and a conditioned piece of 1000 mm, the oversized yield should not exceed 10%. The effective release of ore of such a granulometric composition with significant reserves per outlet can be ensured through the use of high-unit power technical means, which include heavy vibratory feeders, loading and delivery machines with a large bucket capacity and hydraulic excavators. This equipment should work in combination with the most productive transport equipment.

The technical and economic analysis showed that in the variants with free ore release, it is advisable to use a complex vibrating feeder of the RPU type - rail transport using heavy-duty wagons with a load capacity of 20 tons or more. With options with constant filling of the worked-out space and release under the overlying rocks with the use of area release, the most promising is the use of powerful loading and transport machines with ore delivery to the ore outlet. Excavators in combination with underground dump trucks or trolleybuses can also be used for the end release.

Studies were devoted to the problem of the organization of ventilation of mine workings with a complex open-underground method, as a result of which, based on the study of the mode of air movement during filtration through the collapse zone, the use of a combined suction-discharge ventilation scheme was recommended, which allows a wide range of operating modes of suction and discharge fans.

An indicator of the intensity of field exploitation within the open-underground tier is the rate of movement of a high ledge, which, in combination with the cross-sectional area of the developed space, determines the possible production volumes. The speed of moving the ledge, in turn, depends on four main factors: the rate of advance of the front of work in the quarry, the intensity of drilling and blasting, the release and transportation of ore and internal dumping.

The rate of movement of the operational front under the condition of drilling and blasting operations and ore release $v_f^{b.v}$ (m /year) is determined based on the maximum number of relevant equipment in simultaneous operation of the pob, and its unit productivity Q_{ob}, depending on the adopted technology and the parameters of the tier

$$v_{ф}^{б.в} = \frac{n_{об} \cdot Q_{об} \cdot N_{см} \cdot N_{год}}{S_{в} \cdot \gamma_{р}} \qquad (3)$$

where Q_{ob} is the shift productivity of a unit of equipment, t/shift; N_{cm} is the number of working shifts per day; $N_{год}$ is the number of working days per year; $S_{в}$ is the cross-sectional area of the worked space, m^2; $\gamma_{р}$ is the average ore density, t/m^3.

The rate of advance of the front according to the condition of internal dumping v_f (m/ year) is

$$v_{ф}^{отв} = \frac{n_{об^0} \cdot Q_{об^0} \cdot N_{см} \cdot N_{год} \cdot K_{р}}{(S_{в} + S_{k}) \cdot \gamma_{п}} \qquad (4)$$

Calculations have shown that ensuring the required intensity of development is achieved mainly due to the development of the ore release zone.

The variants of the complex open-underground mining method differ in the level of the upper boundary of the open-underground tier and its height and are characterized by different volumes of reserves intended for open, open-underground and underground mining.

With free ore release, the maximum height of the open-underground tier is determined by the safe slope angles of the sides with a deposit capacity of up to 150-180 m. With a higher capacity, the height of the open-underground tier is determined by technological factors, in particular, the capabilities of drilling equipment. With constant filling of the worked-out space with rock mass, the maximum height of the tier is limited by the conditions of breaking in a clamped environment within 70-90 m.

It has been established that at the new deposit, it is advisable to place the upper boundary of the open-underground tier at the level of the maximum depth of the quarry, justified by known methods without taking into account the features of open-underground mining. In the conditions of an exploited field, with overburden lagging and increased requirements for environmental protection, it is advisable to place the open-underground tier partially within the reserves located in the contours of the quarry, with a decrease in the maximum depth of the latter.

Technological options with constant filling of the worked-out space with rock mass and the release of ore under the overlying rocks of the internal dump ensure the greatest efficiency of field development at the maximum permissible height of the open-underground tier located below the limit of open work.

Conclusion. Thus, the conducted research and design studies have established that an integrated open-underground method of developing strong ores is a promising direction for the development of subsurface resources. In the appropriate mining-geological and mining engineering conditions, it allows:

- to reduce the area of environmental disturbance by reducing the volume of external dumping;
- to significantly compensate for the decrease in ore production volumes during the development of deep horizons of quarries;
- to reduce the total volume of overburden in the contour of the quarry due to the development of deep horizons with one high ledge without additional separation of the sides;
- use general schemes for opening deep horizons of a quarry and underground mines.

Combined geotechnology makes it possible to identify the main directions of the implementation of the idea of integrated development of the subsoil in the field of open-underground mining. These include: a combination of technological elements of open and underground mining operations at the stage of treatment excavation, the joint use of open and underground mining operations for ore transportation, the use of a single developed space of open and underground mining operations to accommodate overburden. With a complex open-underground method, all three of these directions are implemented, but they can also develop independently in a wider range of mining and geological conditions. Therefore, an important task of further research should be considered the development of new technological solutions and the substantiation of the principles of their design within the framework of the considered promising areas.

References

1. Puchkov L.A. Sharovar I.I.-Vitkalov V.G. Geotechnological Methods of Deposit Development. – M.- Mining Book Publisher, 2006. - с. 322.
2. Lazchenko K.N. Terentyev B.D. Geotechnological Methods of Development of Mineral deposits. – M.- MGU.- 2000. - с. 75.
3. Demidov Yu.V. On the classification of stopping the combined development of ore deposits // Mining Journal. - No. 4, 1995. - p. 16-19
4. Kazikaev D.M. Combined development of ore deposits. – M.- Gornaya book.- Publishing House. - 2008. - с. 355.
5. Kaplunov D.R. Kalmykov V.N. Rylnikova M.V. Combined geotechnology. - M.: Ore and metals.- 2003. - с. 550.
6. Kaplunov D.R. Rylnikova M.V. Combined development of ore deposits. - M.: Mining book, 2012. - 344 p

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