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EFFICIENT TECHNOLOGY FOR THE MINERAL RESERVES EXTRACTION IN ORE DEPOSITS DEVELOPMENT

Abstract. This article discusses the analysis of mining operations, a review of the literature, and how remaining ore is cleared in interchamber mines on the panel, taking into account the geomechanical and safety conditions. The goal is to create an effective technology for the development of ore deposits that ensure the completeness of mineral extraction when establishing the order and direction of mining pillars in the panel, based on determining the load on the pillars, for each lithological type of rocks that make up the overlying stratum. With the method indicated below, the completeness of the extraction of active reserves of the panel is increased while maintaining the stability of the outcrop. A resource-saving technology for the development of ore bodies is recommended, which ensures the complete extraction of mineral reserves from the subsoil.

Key words: *technology, minerals, development, efficiency of underground mines, resource extraction, pillar, methodology calculation.*

Кен орындарын игеру кезінде пайдалы қазбалар қорларын тиімді өндіру технологиясы

Андатпа. Бұл мақалада тау-кен жұмыстарын талдау, әдебиеттерге шолу жасау, сондай-ақ геомеханикалық және қауіпсіздік жағдайларын ескере отырып, панельдегі шахтааралық шахталарда қалған кенді тазарту тәртібі зерттеледі. Мақсаты – бағаналарға түсетін жүктемені анықтауға негізделген панельдегі тау-кен бағаналарының тәртібі мен бағытын белгілеу кезінде пайдалы қазбаларды өндірудің толықтығын қамтамасыз ететін кен кен орындарын игерудің тиімді технологиясын жасау. Төменде көрсетілген әдіс кезінде ойпаттың тұрақтылығын сақтай отырып, панельдің белсенді қорларын алудың толықтығы ұлғайтылады. Жер қойнауынан пайдалы қазбалар қорларын толық өндіруді қамтамасыз ететін кен денелерін игерудің ресурс үнемдейтін технологиясы ұсынылады.

Түйінді сөздер: *технология, пайдалы қазбалар, өндіру, жерасты кенішінің тиімділігі, қорларды игеру, кентірек, есептеу әдістемесі.*

Эффективная технология отработки запасов полезных ископаемых при разработке рудных залежей

Аннотация. В данной статье рассматривается анализ работы горнодобывающих предприятий, обзор литературы и вопрос о том, как происходит расчистка оставшейся руды в межкамерных шахтах на панели с учетом геомеханической обстановки и с соблюдением техники безопасности. Целью является создание эффективной технологии разработки рудных месторождений, обеспечивающих полноту извлечения полезных ископаемых при установлении порядка и направления отработки целиков в панели, на основе определения нагрузки на целики, для каждого литологического типа горных пород, слагающих налегающую толщу. При указанном ниже способе повышается полнота извлечения активных запасов панели с сохранением устойчивости обнажения. Рекомендуется ресурсосберегающая технология разработки рудных тел, обеспечивающая полноту извлечения запасов полезных ископаемых из недр.

Ключевые слова: *технология, полезные ископаемые, разработка, эффективность поземных рудников, извлечение запасов, целик, методика расчета.*

Introduction

At present, the issues and tasks of rational use of all available mining, geological and technological resources for maintaining the required level of efficiency of underground mines are becoming increasingly relevant. At the same time, one of the most important reserves for increasing the efficiency of mine development should be considered the most complete extraction of reserves due to the subsequent extraction of the remaining pillars. A common system for developing horizontal and inclined ore deposits is the room-and-pillar system of development with subsequent extraction of pillars (repeated mining) [1]. The system is highly productive, however, characterized by significant drawbacks: ore losses in the panel as a whole reach 20 ... 40%, which increase under conditions of increased rock pressure, due to premature collapse of the roof and pillars. The main structural elements in the room-and-pillar system of development are the ceiling (roof of the chamber) and the pillar. Despite the large volume of theoretical and experimental studies on the assessment of the stress state of structural elements of the development system, there is still no final scientifically based approach to the effective design of technological parameters for the development of ore deposits. The generally accepted method for calculating the parameters of the development system [2] is the calculation of the parameters of the pillars and spans of the stopes depending on the depth of development and on the basis of empirical dependencies obtained at specific deposits, which is not always applicable to other similar deposits. Even taking into account the fact that the mining and geological conditions at one deposit can change to the same extent, and the use of the parameters of rock sliding from one section of the deposit to another section can lead to an increase or decrease in the magnitude of the load acting on the pillars. This, accordingly, leads to an increase or decrease in the size of the pillars, loss of minerals, imbalance of the geomechanical structure «pillar – roof» and its collapse. Therefore, the problem of increasing the efficiency of ore deposit development, taking into account the stress-strain state of the massif to ensure the complete extraction of minerals, is an important task from a practical and scientific point of view, the solution of which allows reducing the costs per unit of extracted mineral [3].

The creation and improvement of mineral deposit development technology, optimization of their parameters and control of rock pressure are the subjects of research by many scientists. But despite this, the task of creating and improving mineral deposit development technology remains very relevant [4].

Materials and Methods

Analysis of the work of mining enterprises and specialized literature shows that when developing deposits in complex mining and geological conditions, significant losses of minerals often occur, reaching 20–30% or more of the explored reserves. For the development of flat and inclined ore deposits, open stope systems are widely used. The use of the room-and-pillar system during its use has led to an improvement in the parameters of breaking and an increase in technical and economic indicators. However, when designing key elements of the system, such as extraction panels, outcrop sizes, parameters of inter-chamber and inter-floor targets that perform the function of load-bearing elements to retain pressure, the reasons are insufficiently observed in complex mining and geological conditions. It follows from this that in areas developed by the underground method, collapse chambers are used, which, as a rule, with the destruction reaching the surface [5].

Based on the conducted analysis and review of the state of the issue, a goal has been formulated aimed at creating an effective technology for the development of ore deposits that ensure the complete extraction of minerals by establishing the order and direction of the development of pillars in a panel, based on determining the load on the pillars, for each lithological type of rocks that make up the overlying strata.

In gentle and sloping (up to 30–35°) deposits contain large reserves of non-ferrous metal ores. Such deposits are mined using systems with open mined space, with caving of overlying rocks and, less frequently, with backfilling of the mined space, including hardening mixtures. The most widespread of these systems are room-and-pillar and pillar with caving of overlying rocks [6].

The authors [7] propose a method for developing gently dipping ore deposits, the essence of which is as follows: mine fields are developed with a bench-like front, and the leading bench is developed in alignment with the cutting line of the barrier pillar. The pillar is developed together with the development of mine fields. The sections of mine fields between the front of the cleaning works and the barrier are completely relieved from rock pressure by workings. According to the safe level of stress, the width of the barrier pillar within the next bench is adjusted and the mine fields and the pillar are developed. The mined-out space is filled with hardening mixtures.

A method is also known [8], which includes the development of panel reserves with the formation of belt inter-chamber pillars, the width of which is equal to the drilling width of a self-propelled drilling machine from one of its installations, the filling of the worked-out space of the chambers with hardening mixtures, the extraction of belt inter-chamber pillars and the filling of the newly formed worked-out space between adjacent filled chambers. With this method, the completeness of the extraction of active reserves of the panel is increased while maintaining the stability of the outcrop. The main disadvantage of this method is the filling of the worked-out space.

Results and discussion

Recommendations for efficient technology for the development of reserves during the development of ore deposits. When developing ore deposits using the underground chamber-and-pillar method, the development involves leaving supporting inter-chamber pillars. In the event of destruction of the inter-chamber pillars, the resulting collapse of the overlying strata may cause dangerous deformation of the earth's surface.

Complete extraction of mineral reserves is possible with reliable provision of safety of mining operations and improvement of development technology. The required maximum productivity of the panel can be provided by a room-and-pillar mining system using self-propelled equipment. In this case, technological losses are formed due to leaving inter-chamber and barrier pillars.

Quantitative and qualitative indicators of ore extraction from the subsoil depend on the correctly selected parameters of the development system. They can be improved by increasing production costs. Therefore, the requirement for the development system is that the sum of the reduced costs and economic damage from losses and dilution of the ore be minimal.

Efficient development of mineral reserves during the development of ore deposits was considered using the example of an underground mine, where more than 20 million tons of ore have been developed to date, which has led to the formation of large voids, and some of the ore reserves remained in the inter-chamber pillars (ICP). In order to maintain a stable geomechanical state, it is advisable to begin developing the remaining inter-chamber pillars and to fill the formed voids by caving. Repeated development of ore reserves left in the ICP makes it possible to increase the completeness of the extraction of panel reserves.

A two-stage extraction of the mineral is recommended. The first stage involves the extraction of ore reserves using a room-and-pillar mining system, leaving barrier pillars along the panel boundaries. The second stage involves the extraction of inter-chamber pillars from the open working space, with the collapse of the overlying rocks as they are mined.

Before re-mining, it is necessary to inspect the panels to clarify the geomechanical situation, prevent accidents and warn about the collapse of weakened and unstable pillars. After studying the design documentation and carefully inspecting all the ICP panels, conclusions are made and recommendations for re-mining are issued.

The loads on the ICP are calculated taking into account the sub-arch load formed above the panel area and between the barrier pillars, according to the proposed method (Figure 1).

From the above sequence of panel reserves development it follows that the ore reserves left in the inter-chamber and belt pillars are temporarily inactive reserves. The volumes of these reserves can be determined by the following formula [9]:

$$\boldsymbol{Rint} = \boldsymbol{\gamma h}\left[\boldsymbol{Ksq}\frac{\boldsymbol{\pi d^2}}{\boldsymbol{4}}\boldsymbol{q_{inchp}} + (\text{К}_{\boldsymbol{sq}} - \mathbf{1})(\boldsymbol{l_{sq}}\text{В}_{\boldsymbol{sq}} - - \boldsymbol{l_{cut}}\text{В}_{\boldsymbol{cut}}\text{К}_{\boldsymbol{cut}})\right],$$

Where:
γ – ore density, t/m^3;
h – deposit thickness, m;
K_{sq} – number of squares, pcs;
d – diameter of the inter-chamber pillar, m;
q_{inchp} – number of interchamber pillars, pcs;
l_{bp}, B_{bp} – respectively the length and width of the belt pillar, m;
l_{cut}, V_{cut} – respectively the length and width of the cut, m;
K_{cut} – number of cuts, pcs.

For this purpose, geotechnical monitoring is carried out [10–12], including: seismic assessment of the processes of deformation and destruction of rocks in the rock mass; instrumental observations of the roof behavior; visual monitoring of the state of the working faces and adjacent workings. Seismic monitoring is carried out based on the observation network of the ISSI seismic monitoring system (South Africa). This system includes aboveground and underground parts, which ensures control over the geomechanical situation in all areas of development, including re-development, with the ability to promptly respond to any changes. Instrumental monitoring includes the installation of displacement sensors for the anal-

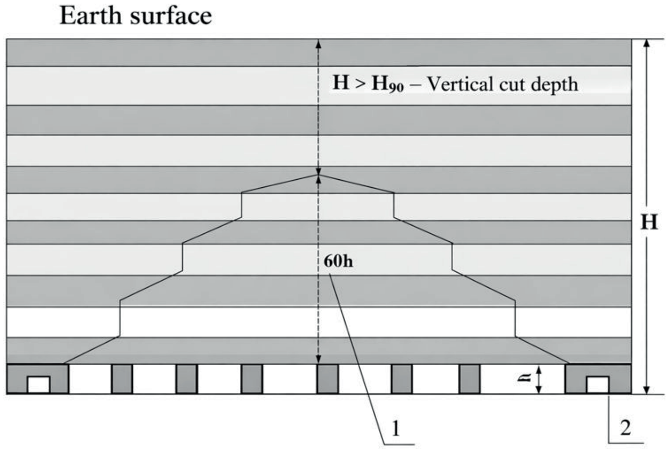

Figure 1. Rework stage: *1 – the contour of the arch formed between the barrier pillars; 2 – barrier sight; H – depth of the deposit; h – thickness of the deposit*

Сурет 1. Қайта өңдеу кезеңі: *1 – тосқауыл кентірек арасында түзілетін күмбез контуры; 2 – тосқауыл кентірек; H – кен орнының жату тереңдігі; h – кен орнының қуаты.*

Рис. 1. Стадия повторной отработки: *1 – контур свода, образуемый между барьерными целиками; 2 – барьерный целик; H – глубина залегания залежи; h – мощность залежи.*

ysis of the quantum-deformed state of the rock mass, which allows for the timely detection of potential collapse zones and the adoption of measures to localize them. Visual monitoring of indicators by linear supervision is aimed at periodic assessment of changes in the state of the roof, barrier, inter-chamber and signal targets, as well as monitoring the state of the mined-out space to ensure safe working conditions.

All of the above activities are aimed at effectively conducting reprocessing without unnecessary losses of stocks in the ICP while observing safety regulations.

The significance of the research conducted

The justification and improvement of technological solutions for the panel-and-pillar mining system based on changes in the structural elements of the system and the optimization of their parameters, ensuring efficiency and completeness of the extraction of ore reserves, is a significant task for mining enterprises using this development system.

Usefulness of the results

Increased recovery of the deposit's reserves is achieved through the implementation of a technology based on dividing the mining area into squares using strip pillars. The size of the square's side corresponds to the distance between the inner walls of the barrier pillars, allowing for targeted redistribution of the load on the structural elements of the mining system.

Unlike traditional methods, the diameter of the inter-chamber pillars within the squares is determined taking into account the sub-arch load formed over the area of the square and between the barrier pillars, according to the proposed method.

An increase in the completeness of mineral extraction is also achieved by mining inter-chamber pillars under conditions of controlled collapse within a limited area of the panel within each square.

Preliminary caving within a square provides the opportunity to develop barrier pillars from the adjacent side of the neighboring square, using the resulting clearing space.

Optimization of losses and reduction of dilution of mined ore are achieved by regulating the size of squares and the value of the permissible sub-arch load.

Informativeness of the conducted research

The proposed solution to the current scientific and technical problem of increasing the efficiency and safety of extraction of flat ore deposits by creating process flow charts based on new principles of designing development systems can be useful for mining industry specialists, mining scientists, as well as doctoral students, master's students, and students majoring in «Mining».

Practical significance of the results

A new method for mining reserves within a panel has been developed, allowing for ore extraction without the need for backfilling, which significantly reduces mineral losses in inter-chamber pillars and increases the completeness of reserve recovery.

The developed technological solutions take into account the important relationship between economic efficiency and environmental safety. This is achieved through the rational use of underground space, the reduction of manual labor intensity, the development of geotechnologies, compliance with anthropogenic impact regulations, the use of recycled resources and substitute materials, and the mitigation of potential negative consequences.

It has been established that by pre-demolishing the supporting pillars and then controlled roof collapse to a predetermined height, it is possible to effectively remove barrier pillars from the cleared space of adjacent panels. With proper field preparation, this technology can also be used for subsequent removal of supporting pillars.

Recommendations for implementation

The proposed research results are recommended for use in the development of medium-thickness ore deposits using room-and-pillar and panel-and-pillar mining systems to increase the completeness of extraction of mineral reserves.

Conclusion

A resource-saving technology for the development of ore bodies is recommended, ensuring the complete extraction of mineral reserves from the subsoil.

The results of the implementation of the recommended technology make it possible to increase the level of industrial safety at mining enterprises and create prerequisites for an economical technology for the development of ore deposits in order to increase the completeness of mineral extraction.

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