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Sublevel Mining System with Artificial Pillars Made of a Hardening Backfills for The Development of Veins in Difficult Geomechanical Conditions

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Annotation: In underground mining of deep horizons, rock pressure can manifest itself in any form, posing a serious threat to the lives of workers, disrupting the normal course of mining operations and reducing the efficiency of mining.

The solution to the problem of controlling rock pressure is becoming very important for underground mines leading the development of vein deposits at a depth of more than 250 m.

The aim of the work is to develop and substantiate technological schemes that ensure safe and efficient development of deposits in difficult mining and mechanical conditions.

In the work, the factors of redistribution and dangerous concentration of stresses in the developed ore massif are established, methods of rock mass management in difficult geomechanical conditions are studied, their advantages and disadvantages are revealed.

It has been determined that the sublevel development system with the combined use of existing methods for controlling rock pressure and the use of self-propelled equipment in the production processes of this system is currently one of the progressive ones in improving and expanding the scope of its application.

On the example of the Zarmitan gold ore zone, the variants of technological schemes of a sublevel mining system combining a combination of different methods of controlling rock pressure, allowing minimizing the disadvantages of one using the advantages of others, are considered.

sublevel mining systems with artificial supporting retaining pillars of polygonal shape and sublevel development systems with artificial supporting retaining columnar pillars are proposed, which allow reducing the loss of ore in intervening pillars, ceilings and secondary dilution. In addition, artificial pillars, perceiving compressive-tensile stresses to themselves, prevent their concentrations and create safe conditions for working out adjacent and lower horizons.

Key words: Rock pressure, geomechanical processes, development system, structural heterogeneity, pillar, massif stability, sublevel collapse, sublevel drifts, compensation chambers, ore passes, rising, ore body.

Introduction.

The solution of the problem of rock pressure management is very relevant for a number of underground mines and is largely held back due to insufficient knowledge of the nature and mechanism of geomechanical processes and phenomena arising from the deepening of mining operations in tectonically disturbed rock massifs under the influence of numerous natural and man-made factors. A complex geomechanical situation develops during the development of vein deposits, which are peculiar to ore deposits.

The host rocks are susceptible to brittle fracture and are potentially susceptible to impacts [1]. At the stage of design and construction of underground mines, for their safe and efficient operation, it is necessary to determine the parameters of geotechnology in a timely manner, taking into account the specific geological and geomechanical conditions of mountain massifs [2, p.67; 3, p.913].

The mining system with shrinkage of ore, used in the conditions of gold deposits with stable ore and rock of medium stability, is obsolete and has low TEP. The sublevel chamber system has higher technical and economic indicators, including recovery rates, relative to the system of horizontal layers. Therefore, for the development of vein deposits, the system of horizontal layers with an ascending order of mining and dry

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backfilling of the developed space is accepted as the main one [4, 5]. Factors such as structural heterogeneity, separation of ore bodies by rock interlayers[6], the complex geometry of the formed mined spaces, blasting operations[7], the presence of numerous and diverse pillars can lead to redistribution and dangerous concentration of stresses in the ore massif being developed and as a result may be additional causes of negative manifestations of rock pressure.

Currently, many mines are revising previously established conditions to replenish their capacities, and as a result, significant parts of off-balance sheet ore reserves are transferred to balance sheet ones. At the same time, all newly commissioned ore bodies are located on previously worked horizons, often near with extinguished blocks, or on the flanks of deposits [8-9-10]. It is not excluded that such a decision will be made at the mines of the Zarmitan gold ore zone, since here more than 80% of the reserves are represented by ore bodies containing, in addition to the main, from 2 to 8 useful components with industrial content, and only in 20% of cases these components are extracted. Reserves of off-balance sheet ores sometimes exceed 2-3 times the reserves of metal than its reserves in balance sheet ores. They are assigned to this category for a variety of reasons.

In addition, the lost in the form of pillars and ore fines on the recumbent side of the block, is distributed over very large areas of mined veins. If it is necessary to organize the extraction of these losses, it is required to perform a large volume of labor-intensive and dangerous work to restore or re-tunnel old mine workings.

The purpose of this work is to develop safe technological schemes based on ensuring complete, high-quality development of balance reserves, conditions of obstacles to stress concentration, and as a result of maintaining the integrity of the array without disruption for future development of the remaining reserves.

Materials and methods. The analysis of technical literature and the practice of well-known large mining companies show that, depending on the degree of stability of the host rocks and the design features of the development systems used, the maintenance of the treatment space is carried out in numerous ways [11,12], which have their advantages and disadvantages, which are represented by a variety of options with different technical and economic indicators. The use of filling from hardening cement and other alternative materials to it is expanding [13, 14]. Some mines, when mining thin ores in difficult conditions, use combined methods of massif management based on intensive cleaning operations from sublevel workings using broken ore as a temporary backfill to maintain side rocks [15, p.46].

The opinion is given about the indisputable and obvious advantages of the sublevel collapse systems over other equivalent technologies [16,17], as a more economical and progressive way of development. With this development system, the preparatory-rifled workings (sublevel drifts, compensation chambers, ore passes, etc.) unload the array, with the redistribution of stress concentrations inside and outside the excavation unit. Safe conditions are being created for mining adjacent ore bodies and underlying horizons.

The analysis of underground mining operations of the mines of the Zarmitan gold ore zone predetermines in favor of sublevel mining of ore with small-diameter wells, including progressive technology and mechanization of work with self-propelled equipment.

It should be noted that the use of self-propelled equipment [18, 19] in the production processes of underground mining by a system with sublevel collapse of vein deposits opens up new opportunities for improving development systems, requires a complete change in the existing technological preparation schemes (working horizons, excavation units and the mine as a whole) and selection of their parameters.

Thus, the creation and substantiation of new resource-saving technologies with sublevel collapse, combining a combination of different methods of rock pressure control, allowing to minimize the disadvantages of known technologies is one of the progressive, but poorly studied, the area of their safe and effective application has not been determined and requires additional research.

Results. To develop the reserves of the Zarmitan gold ore zone, two options for technological schemes by sublevel caving with a combined method of controlling the rock mass are considered and proposed (Figs. 1 and 2).

A distinctive feature of the first version of the technological scheme (Fig. 1) is the combined use of methods for maintaining the mined-out spaces with artificial pillars of a polygonal shape, formed by laying the hardening material in specially prepared nests (workings).

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There are two possible options for training schemes - block and precinct. It is advisable to use the block scheme when working out ore bodies that are short in length. It is advisable to excavate reserves with a significant length of the ore body according to the precinct scheme.

In block schemes, two flank insurgents are carried out. One of them ore serves as a compensation chamber, and the other field serves as an ore pass from the sublevels.

In the precinct training schemes, there are two rebels on the flanks and one field in the center of the block. At the same time, the flank rising ones are used as compensation chambers and for removing the exhaust air stream, and the central rising one serves as an ore pass from the sublevels of both flanks - left and right.

In the precinct schemes, it is also envisaged to carry out crossovers connecting adjacent sublevels to each other, which are necessary to remove polluted air and release associated ore from the sublevels. In the future, these crossovers will serve as a chamber for pouring hardening backfill material during the formation of an artificial pillar. The dimensions and distances between crossings are determined according to the standard ultimate strength of the filling material, which is determined depending on the mining and geological and mining conditions.

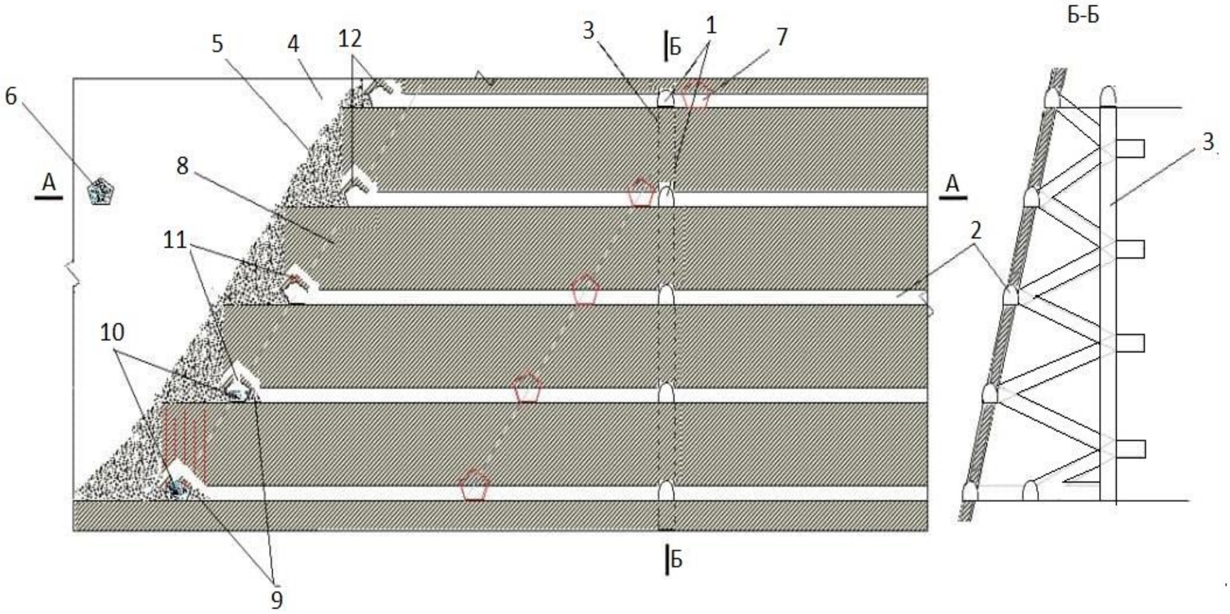

Fig. 1. Sublevel mining system with artificial pillars of polygonal shape from the hardening fill: 1-crosscut to the ore pass; 2-sublevel drift: 3- ore pass; 4- open developed space; 5 - broken ore; 6-artifiicaial polygonal pillar; 7 - the place where the next pillar of polygonal shape was laid;
8-solid ore; 9- a partition from an ore embankment; 10- the position of the excavation (vessels) for the pillar device, in the stage of its construction; 11 - the position of the excavation (vessels) at the stage of formation of the pillar, 12 - the position of the excavation with overlap (ore embankment) before laying the pillar; 13-drilled wells.

The preparatory and cutting works in both variants include the driving of the rising, inclined sectional transport exit (STC), orts of access to the STC and ore pass, access to the section STC and ore pass in the concentration horizon. Sublevel drifts are also carried out as grooved ones. The height of the sublevels is 10-15 m, which is determined by the thickness of the ore bodies and the possibility of of curvature of wells.

The procedure for conducting cleaning works in the case of development with artificial pillars of a polygonal shape is carried out with a lag from the upper sublevel by 10-12 m.

Works on the construction of artificial pillars are carried out simultaneously on all sublevels in the following order:

1. Expansion and formation of the dome of the ceiling above the sublevel drift is carried out to the required size by drilling, loading and blasting a set of drills in the shape of a wedge. In this case, edge drifts are drilled at an angle of at least 45 degrees.

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2. The ceiling above the extended part of the sublevel with a recess is formed by driving inclined workings in the usual way with a thickness of 2.0 m.

3. A gap is formed at the top of the ceiling for pouring the hardening material and creating an artificial pillar. The slot is formed by drilling, loading and blasting a set of parallel boreholes.

4. Cleaning the base of a part of the sub-floor under the dead-end pillar from foreign objects, the scattered ore serves as a wall for the artificial pillar from the bottom-hole side.

5. To form the opposite wall, to create an artificial pillar, ore is poured, followed by the release of ore during the development of the lower sublevel.

6. The filling of the created working is carried out with a hardening fill with the addition of large rock aggregates to its composition.

Discussion. The main advantages of this system are ensuring reliable safety, more durable pillar material, simple organization of cleaning work and lower material costs in comparison with the development system with the laying of a treatment space, relatively high qualitative and quantitative indicators of ore mining, wide possibilities of using self-propelled machines in production processes and operations cleaning works.

The main disadvantages of this development system are the tight connection between the ore breaking processes and the operations of pillar construction when approaching the line of their formation, the low level of mechanization when creating pillars, significant labor and time spent on the erection of pillars.

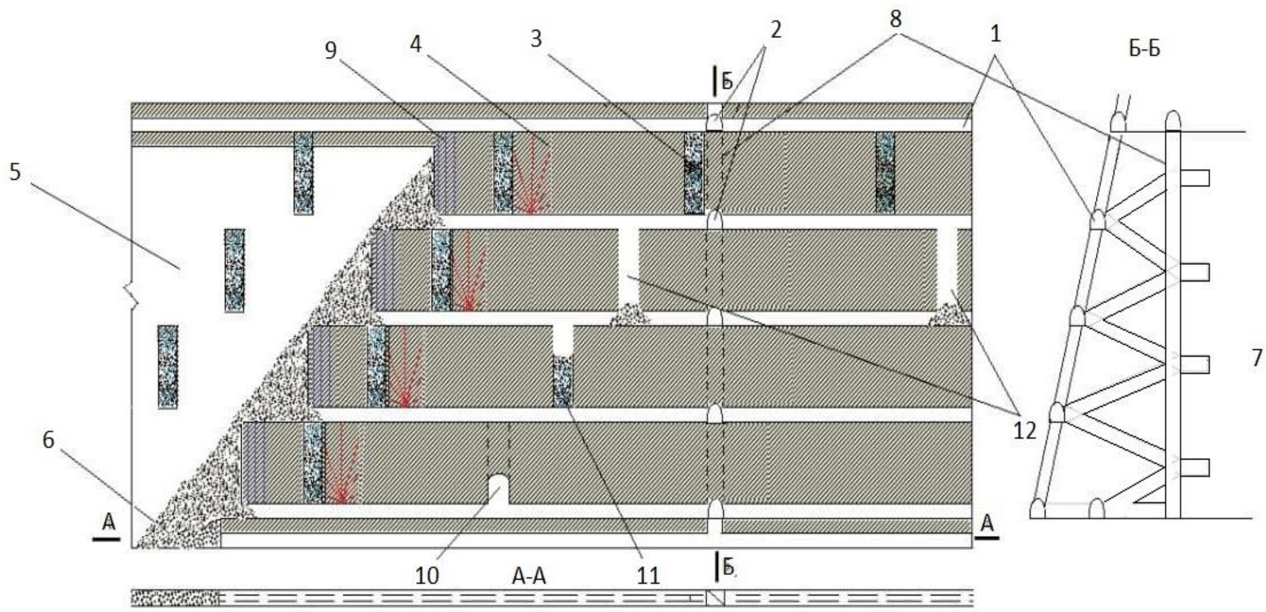

Fig. 2. Sublevel development system with artificial columnar pillars: 1- sublevel drift; 2-crosscut to the ore pass; 3- columnar artificial pillar; 4- drilled wells to form a compensation chamber; 5- developed open space; 6-broken ore; 7- solid ore, 8-ore pass; 9- a partition from an ore embankment; 10- the position of the development for the device of the columnar pillar, at the stage of its formation; 11- the position of the development in the stage of the formation of the columnar pillar; 12 - the position of the working with overlap (ore embankment) before laying the columnar pillar.

In the second version of the sublevel development system with artificial columnar pillars, the treatment works and the formation of pillars (Fig. 2) is carried out in the following order:

1.Previously passed failures, starting from the upper sublevel in the direction from the flanks to the central part of the site, are filled in turn with a hardening fill. This order of filling can be carried out simultaneously on the subsequent lower sublevels. It should be noted here that the process of creating an artificial pillar in the considered scheme does not have a rigid connection with other processes of cutting and cleaning operations. Therefore, it is possible, even necessary, to carry out filling work simultaneously with

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the driving of sublevel drifts with a lag of one cross, since the effectiveness of the hardening filling depends on the time of hardening to monolithic concrete.

2.Cleaning work starts from the upper sublevel simultaneously in two flanks towards the center of the site. Advancement of cleaning works in the upper sublevel from the lower and subsequent sublevels should be at least 10-12 m.

Ore breaking is carried out using a set of fan holes. Wells are drilled with self-propelled drilling machines. During blasting, part of the chipped ore remains in the foot of the sublevel drifts, while the other part falls down through the worked-out space.

The main advantages of this system are safety assurance, simple organization of treatment works and the construction of artificial pillars, a lower level of labor and material costs than development systems with the laying of a treatment space, relatively high qualitative and quantitative indicators of ore mining, the possibility of flexible transition of schemes from one to another. A distinctive feature of this scheme in comparison with the first option is the practical independence of the filling process with the processes of cutting and cleaning work. This makes it possible to carry out filling work, simultaneously during the period of driving sublevel drifts, while prolonging the time of hardening of the filling material and increases the strength of the pillar.

The main disadvantages of this system are the high consumption of hardening material and a significant investment of time and labor in the construction of pillars.

In both considered options, the delivery of broken ore from each sublevel before ore passes is considered to be carried out autonomously, which eliminates the need to create a haulage horizon.

All operations for the construction of artificial pillars in the outlined technological schemes are carried out mainly with the help of self-propelled equipment available at the mines of the Zarmitan gold ore zone.

Conclusion. On the example of the Zarmitan gold ore zone, with the aim of safe and complete mining of ore reserves in weakly stable massifs and stress concentration zones, variants of a sublevel mining system with artificial support retaining pillars from a hardening polygonal and columnar fill are proposed.

Safe conditions and completeness of working out in the proposed variants are achieved by using a complex of preparatory-rifled workings of a sublevel development system as cut-off slots for removing and redistributing stress in a rock mass and with the storage of borken ore in combination with artificial support retaining pillars from a hardening backfill.

The role of the artificial supporting pillars from the hardening backfill is to ensure the maintenance of the enclosing rocks of the chamber in a stable state, which allows to reduce the separation of side rocks and secondary dilution, to reduce the pressure of the enclosing rocks on the magnetized ore and to improve the release conditions. The pillars perceive compressive-tensile stresses, prevents their concentration and creates safe conditions for the development of adjacent and lower horizons.

The proposed technological schemes make it possible to preserve the integrity of the rock and off-balance ore massifs around the worked-out spaces, which makes it possible to work out the remaining off-balance reserves safely and without difficulty when transferring them to the balance reserves. Schemes provide the ability to quickly switch to another scheme if conditions change.

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