N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES OF GEOLOGY AND TECHNICAL SCIENCES
ISSN 2224-5278
Volume 1, Number 433 (2019), 90 – 97 **https://doi.org/10.32014/2019.2518-170X.11**

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CURRENT CONDITION AND OUTLOOKS OF SUSTAINABLE DEVELOPMENT OF CHROMITE UNDERGROUND MINING AT LOWER HORIZONS OF MINES OF THE DONSKOY MINING AND PROCESSING PLANT

Abstract. The article considers the issues of current condition and outlooks of development of underground mining of Donsk chromite mines. With the transition of mining operations to deeper levels, the geomechanical situation is getting considerably more complicated, especially for the development of stope sills that poses the need to solve the issues of developing measurements ensuring the increase in working stability. One of the most radical measures is the development of designs of artificial stope sills according to the option of development systems accepted for lower horizons of the “Ten Years of Independence” mine.

Based on the analysis of the methods for the creation of artificial stope sill on the draw and delivery level, it is proposed to develop the design with reinforced concrete stable support platform of the artificial stope sill made of concrete consolidating stowing in systems of uncontrolled block caving. At the draw and delivery level there is a bearing structure of the element of the development system that can bear extremely high mine pressure and ensure enhanced stability and reliability of transport crosscuts for the delivery of ore mass with the use of self-propelled equipment. The targeted solution of the development issue is essential at the development of chromite reserves with combined geotechnology for safe and sustainable development of underground ore mining at deep levels of deposits Millionnoye and Almaz-Zhemchuzhina of the Donskoy mining and processing plant.

Keywords: development field, technogenic collapses, underground technology, the extraction of chromium, uncontrolled caving, mass, mine technical and mining geological conditions, geomechanical conditions of the massif.

Introduction. Donskoy mining and processing plant develops chromite deposits of the South-Kempirsay massif in Western Kazakhstan, which ranks second with the reserves and is one of a kind in terms of quality, thus totally providing for the Republic’s own needs in chromite raw materials and the needs of the post-Soviet countries and exporting the ore and its concentrate to foreign countries.

At present, the main volume of ore at the Donskoy mining and processing plant is produced underground at mines “Molodezhnaya” and “Ten Years of Independence” commissioned in 2001. The “Ten Years of Independence” mine hosts 84% of chromite ore of the Donskoy mining and processing plant. Only its small part occurs at the depth of from 250 to 400 m from the surface. According to the existing classification, the major volume is located at medium (up to 600 m) and deep (from 600 to 1,500 m) levels [1-3].

Taking into account geomechanical and geotechnical particularities of mining of ore deposits at deep levels and especially ore bodies of the mines “Millionnoye” and “Almaz-Zhemchuzhina” of the mine “Ten Years Of Independence”, the important factors are the study of the mass behavior in the process of stoping, pattern of formation of caving areas, development of geomechanical processes, formation of pressure on supports of mine workings as well as the selection of the most rational process charts of ore deposits mining.

Great thickness of ore bodies of chromite deposits developed underground and weak stability of the ore mass and host rocks once determined the selection of the system of uncontrolled caving of ore and superincumbent rock. At present, it is applied at both mines. However, the major reserves of the "Ten Years of Independence" mine occur at deeper levels that of "Molodezhnaya" and their development is related to high pressure in less stable rocks. As mining operations go deeper in the deposits of Donsk chromites and nears 400 ÷ 600 m, the ore and rock masses with high fracturing are classified as unstable [4-6].

In these conditions, one of the significant drawbacks of the used method of technology unavoidably results in the worsening of the geomechanical situation and distribution of mine pressure in stope sills. Due to this reason, the structural elements of draw workings of the mined block are located in the zone of high (bearing) mine pressure arising and rising with the increase in the development depth and length of the stoping front. And this complicates and raises the price of maintenance and operation of the draw level [7-9].

The methods of research. In harmony with the further development of underground mining at the Kempirsay chromite deposit, there is an interest in generalization of the current condition of the chromite ore mining at the mines. For underground mining of chromite ore, the Donskoy mining and processing plant uses the technology of ore uncontrolled caving [10-12] (figure 1), which is classified as class two of the development system according to Prof. V.R. Imenitov's classification [10].

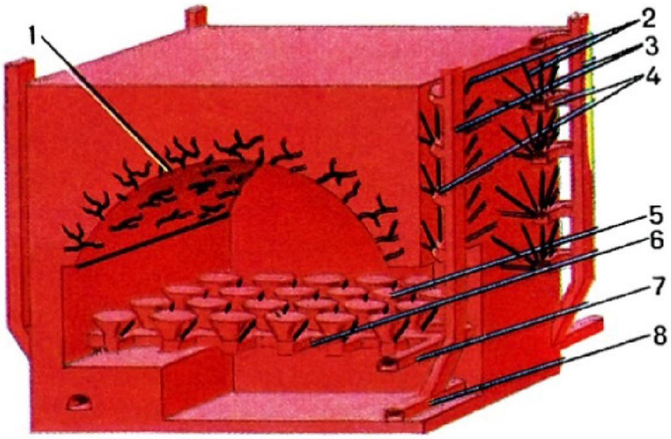


Figure 1 – Classical option of the system of ore uncontrolled block caving:
1 – Dome of the uncontrolled caving area; 2 – cutoff holes; 3 – lateral raises; 4 – drilling cuts;
5 – discharge cones; 6 – scraper drift; 7 – connecting crosscut; 8 – haulage crosscut

In spite of rather typical requirements within the technology, it provokes great interest among mining production engineers in its application due to its cheapness and simplicity since there is no need to drill holes for breaking, driving sublevels and lifting drilling and other equipment onto them. At that, it allows saving on explosives and materials, on supports of workings, ventilation and other expenses. Therefore, this technology in modern conditions remains the most appropriate and low-cost in terms of economy, efficiency and safety.

The case history of the technology at underground mines of the company *De Beers* (South Africa) revealed that the cost of mining is commensurate with the open-cast mining cost. In addition, of special interest is the practice of those working using this technology and belonging to the authors [11], as well as the description of experience of efficient operation of several foreign mining companies: diamond mines "Finch", "Premier" and "Koffiefontein" (South Africa), copper-nickel mine "North Sparks" (Australia), copper-molybdenum mine "Henderson" of the company "Climax" (USA) and mine "El Teniente" (Chili) as well as iron deposits in Ukraine in the Krivoy Rog basin.

With the transition of mining operations to deeper levels of ore mining at "Millionnoye" mine, the KAZGIPROTCVETMET project has corrected the procedure of preparation and development of reserves of the deposits of the second order of construction at the Millionnoye and Almaz-Zhemchuzhina mines. From the border of separation of applied development systems it will be mined using the system of down-rising horizontal layers using cut-and-fill stoping and self-propelled equipment.

With regards to the development system involving uncontrolled ore caving, the KAZGIPRO-TCVETMET project provides for the creation of artificial (concrete) stope sill (figure 2) at the height of

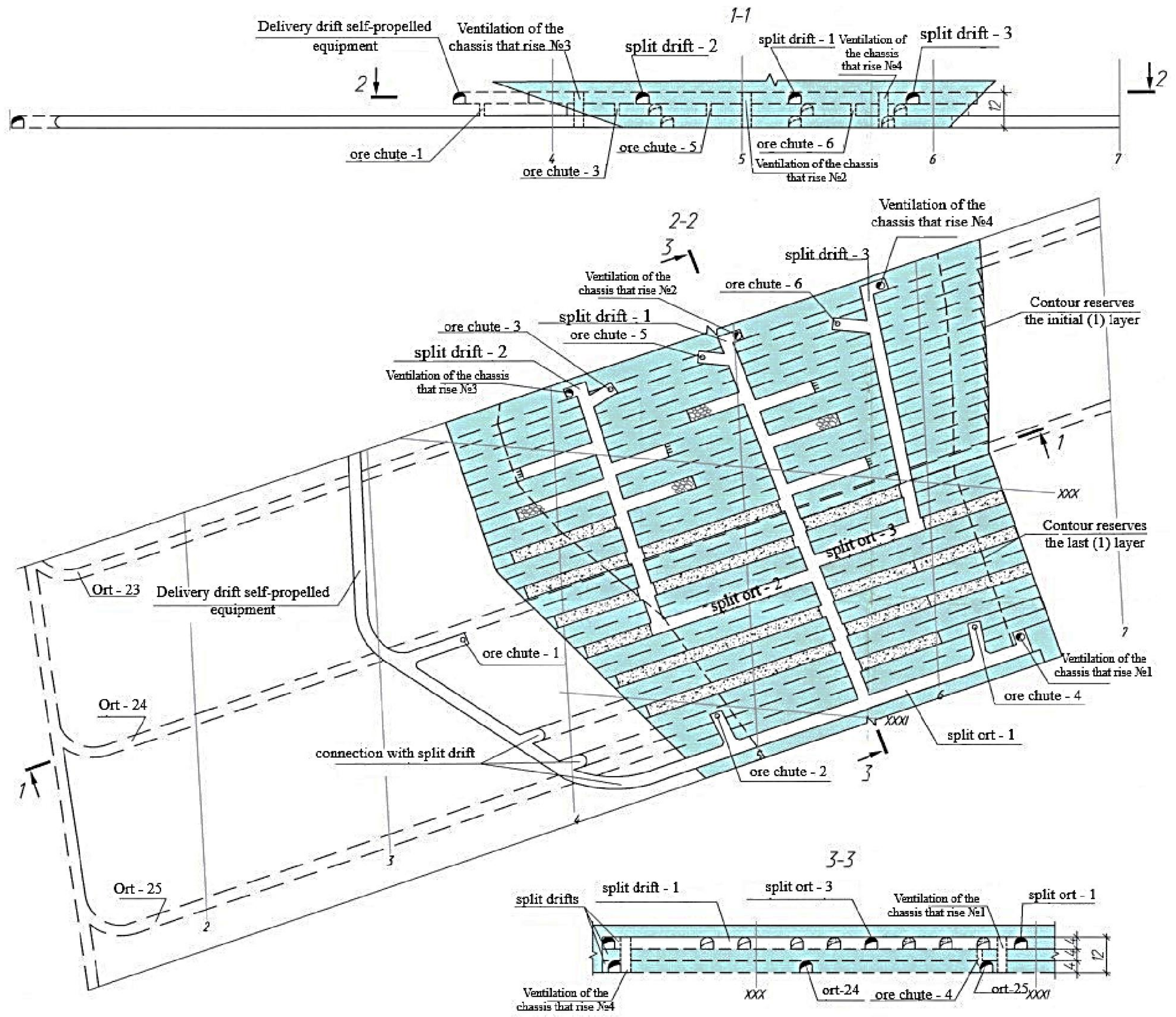


Figure 2 – System of ore block caving with artificial stope sill made of consolidating filling

12 m for the system of block caving by means of developing the reserves of the stope sill with three 4-m high filling layers. This is done with the purpose of reducing mine pressure and conserving all reserves of the block of development and face headings in the period of mining [13].

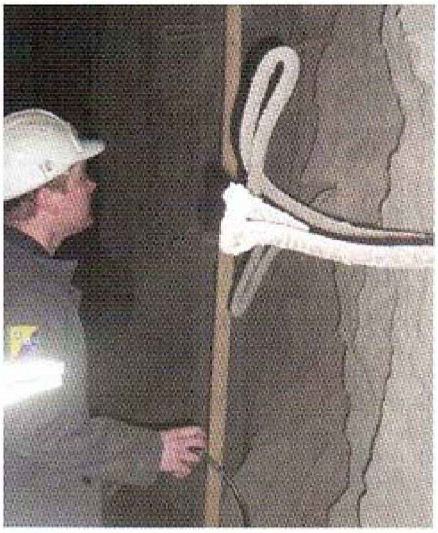
To drive and maintain development headings driven in the filling mass and to examine the strain-stress state of the filling mass and stability of headings there is very little information today related to the mining practice (at underground mines of the Arctic branch of joint-stock company "GMK" Norilskiy Nickel" in Talnakh and Octyabr deposit) [14].

One of the perspective directions of development and improvement of process charts of preparation for blocks is allocation of development headings in the filling mass. To this end, a 1,000 m deep working was driven in the filling mass at mine 2 of the Octyabrskiy deposit, which is around 248 m long.

The deformation process of the contour mass of the heading at the development of underworking span is progressive. And as the driving increases, the deformation intensity of contour mass of workings also rises, especially in the 50-m second zone. This is accompanied with the fracturing in the concrete. Shears at the contour of the working increase and reach around 40-50 mm. In the third zone, which is around 120 m long in the filling mass, there is a sharp displacement up to 80 and more mm at the contour of the working and in the concrete there starts a process of fracture emergence and extension, fractures of layers of the filling mass. Destruction of the filling mass come in the form of sloughing zones in the sides of the working, earth spring, slip formation in the layers of the filling mass and caving of detached concrete slabs. Such kinds of destructions took place mainly at the sections of the working fixed with a combined support.

There are also destructions of the working walls driven in the filling mass at the mine "Taymyrskiy" of the Arctic branch of joint-stock company "GMK" Norilskiy Nickel" [15]. The most part of destructions in the working walls driven in the filling mass were in the middle of the working wall. At that, the wall bent inward the mass, which is evident from the wooden pole the lower part of which rests against undestroyed working wall. Figure 3a shows the initial stage of destruction of the working wall. The change of the form is accompanied by the destruction of the contour part of the filling mass. The depth of the wall destruction is around 40 cm, which is seen by the length of parts of anchors protruding from the wall (anchors are 1.8 m long). Fractures are formed in the lower part of the wall which has not yet detached from the main filling mass. Figure 3b shows on a larger scale the subsequent stage of the wall destruction with a net of large and small fractures parallel to the sidewall of the working.

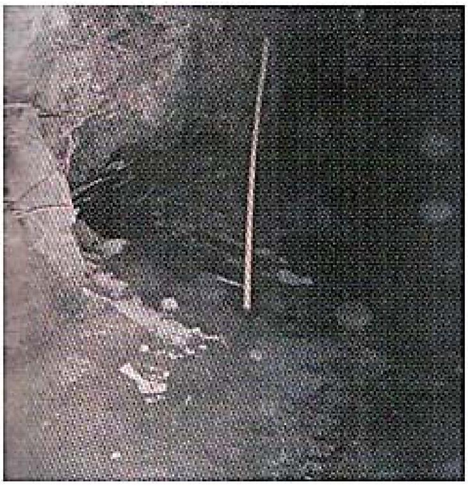
Figure 4a shows "final" stage of the wall destruction in the filling mass of the working driven far from junctions. If the mine technical situation changes, the destruction of the filling mass in this place of



a

b

Figure 3 – Stages of destruction of the working wall driven in the filling mass:
a – Initial stage of destruction of the working wall; b – Subsequent stage of the wall destruction



a

b

Figure 4 – Final stage of destruction of the filling mass in the wall of the working:
a – Workings driven far from the junction; b – Workings driven in the filling mass

the wall can continue. At that, the depth of the wall destruction is around 2 m, which is evident from the wooden pole set at the initial contour of the wall.

Figure 4b shows the destruction of the filling mass at the section of junctions of the mine workings along the whole contour of the wall where only the roof with the incumbent lump of the filling mass is not destroyed. Besides, it was noted that staged destruction of concrete filling took place despite the fact that this exposure was fixed with horizontally established concrete bars and is inefficient since the bars turned out to be parallel to the layering. They did not connect the layers and did not enhance the stability of the concrete scour.

Based on the above-given illustrations of destruction of the filling mass and operational practice of driving the working in the filling mass at the underground mines of "Norilsk Nickel" in the Talnakh and Octyabr deposit, at the present time it is possible to mention only just-begun scientific research and practical works.

Field of application of research results. It is necessary to note that based on the research results, the most complicated in terms of geomechanics in the system of uncontrolled ore caving is workings driven in the stope sill [16-18].

In spite of a three-layer support of scraper workings, SVP 27 (interchangeable special profile) with quite dense setup of frames has not always been reliable and stable. Therefore, in the conditions of mining at lower levels of Donskoy mining and processing plant it is necessary to go over to the creation of artificial concrete stope sill [19, 20].

Widespread development of thick fractured fields resulted in the urgent need to improve the designs of stope sills with the view of considerable enhancement of their strength characteristics, stability, able to bear high dynamic loads posed by large volumes of caved ore mass. As previously noted, conventional funnel-shaped and then trench designs of stope sills in the system of uncontrolled ore caving do not demonstrate reliable resistance to both caved mass and mounting mine pressure.

At the same time, there was a need in alternative to gravity ore drawing through funnels and draw points, which is a bottleneck in highly productive caving systems. With the purpose of intensification of ore drawing process domestic mining companies have adopted vibrating mechanisms that played positive role in the growth of mining productivity.

To tackle the issues of designing artificial concrete stope sills, the staff of the Mining Institute after D.A. Kunayev developed the design of artificial concrete stope sill [21] on a stope sill-support basis ensuring sufficient reliability, stability and operability of scraping drifts.

To illustrate the process of erection of support structural elements and subsequent analytical calculations, the major working of the stope sill was considered - scraping drift with the optimal clearance of $2_{rв}$=2.0 m situated at the depth of 800 m. At the first stage, in harmony with the mine technical conditions of the ore deposit development as well as thickness and accepted parameters of stopes, in particular their

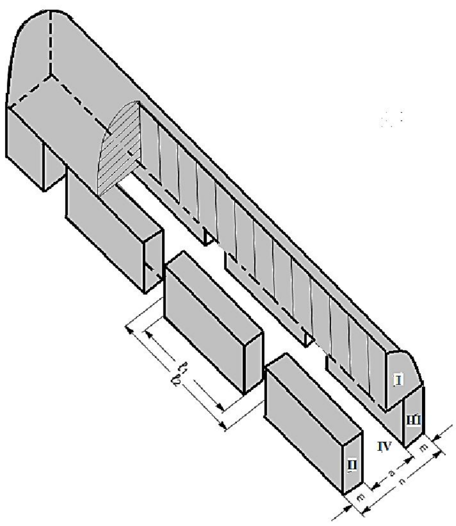


Figure 5 – Principle diagram of the concrete stope sill and sequence of its erection

height hк, the value caved rock arch hоб is calculated, which form the load on the support of workings in the stope sill. To this end, functional dependence $h_{св}$=f ($h_{к}$,) is used based on the relation:

Next, based on the established plastic range of stress, the advisability of erection of artificial stope sill is established using the parameter $h_{об}$ > 90-100 m.

The principle diagram of the concrete stope sill and sequence of its erection are represented in figure 5 with a side cut for clarity of processes [22].

Discussion of results. At the erection of the design, at first service roadways I and II are driven stagewise for subsequent erection of support structures by means of filling the working s with concrete mixture with estimated bearing capacity. The design width of roadways I and II is accepted based on maximum probable loads (which will be mentioned later), namely m=2 meters or гв=1.0 m. In line with table 1, specific pressure at kH=1.0 for this working driven at the depth of H=800m in the rock mass will amount to $q_{vд}$=15.9 t/m^2, and for solid ore qуд=20.4 t/m^2. As a result, the number of framer per running meter in the first case will equal NП=1.0 pc/running meter, in the second case NП = 1.36 pc/running meter. This is true in the tough operating conditions of support SVP 22 (interchangeable special profile). The need to ensure such conditions is explained by the possibility of preliminary relief of excessive pressure caused by the formation of plastic range of stress by activating the yielding units. Later, this process favorably affects the operation of concrete supports. Thus, depending on the host rock mass (ore solid and rock mass) the permissible density of installed support frames of interchangeable special profile SVP-22 is 1.5-1.0 pc/running meter.

After driving and supporting the roadway I, it is filled with concrete mixture. At that, straight arches are installed in places of design location of draw points for the formation of the cavity of required dimension. To perform subsequent analytical calculations the following parameters have been accepted: the length of one support section=5.0m, the distance between the axis of draw points = 7.0 m (figure 4.1). Operations in roadway II are performed according to the similar chart.

After completing the operations on the workings of the first and second stage and on concrete curing during 28 days, it is possible to start operation on working III (third stage) with base width n = 6.2 m. The calculations of the support reveals that in this case to support the working it is necessary to setup a two-layer support made of interchangeable special profile SVP-27. For rock mass – 6 pc/running meter, for ore solid - 7 pc/running meter. It is necessary to note that at this stage an experimental option is considered with maximum height of caved rocks equaling $h_{об}$ = 500 m. At lesser values of hоб within 250-300 meters, structural parameters of the stope sill significantly change. The developed methodical chart allows hands down designing of calculations for real conditions.

After erecting the support, it is necessary to thoroughly cleanse the base of the working from the sides of roadways of stages I and II, to lay metal screen and lay and fasten bars of rolled steel to improve strength of ceiling of stage IV roadway (scraping drift) and improvement of connection with bearing supports [23].

Conclusions. With the transition of mining operations to deeper levels, the geomechanical situation is getting considerably more complicated, especially for the development of stope sills that poses the need to solve the issues of developing measurements ensuring the increase in working stability. One of the most radical measures is the development of designs of artificial stope sills according to the option of development systems accepted for lower horizons of the “Ten Years of Independence” mine.

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The targeted solution of the development issue is essential at the development of chromite reserves with combined geotechnology for safe and sustainable development of underground ore mining at deep levels of deposits Millionnoye and Almaz-Zhemchuzhina of the Donskoy mining and processing plant.

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ДӨҢ КБК ШАХТАСЫНДАҒЫ ЖЕРАСТЫ ТАУ-КЕН ЖҰМЫСТАРЫНЫҢ ҚАЗІРГІ ЖАҒДАЙЫ МЕН ДАМЫТУ МӘСЕЛЕСІ

Аннотация. Мақалада ДӨҢ хромитті шахтасының жерасты тау-кен жұмыстарының қазіргі жағдайы мен болашақта дамыту мәселесі қарастырылған. Жерасты тау-кен жұмыстарының терең деңгейжиектерде горизоннтарда жүргізілуіне байланысты геомеханикалық жағдай күрделене түседі, әсіресе блоктың түпкі қазбаларында, туындаған мәселелерді шешу мақсатында қазбалардың орнықтылығын арттыруды қамтамасыз ететін іс-шараларды ойластыру қажеттілігі туындайды. Ең радикалды шаралардың бірі жасанды түп қазбалы блоктың конструкциясын әзірлеу болып табылады, қабылданған қазу жүйесінің нұсқасы «Қазақстан тәуелсіздігіне он жыл» шахтасының төменгі деңгейжиектеріне арналған.

Негізгі талдауға сүйене отырып, деңгейжиекте жасанды түп қазбалы блоктың кен шығару мен жеткізу тәсілдерін құру бойынша мәселелені шешуге бетонды-қатпалы толтырмалы темірбетонды платформалы тұрақты-тірек конструкциясын әзірлеу ұсынылады, кеннің қабатаралық өздігінен құлау жүйесінде, кен шығару мен жеткізу деңгейжиегіндегі қазу жүйесінің салмақ түсетін конструкциялық элемент ретінде қолданылады, өздігінен жүретін жабдықтарды қолданумен кен жеткізу кезінде, көліктік квершлагтердің жоғары тұрақтылығы мен сенімділігін қамтамасыз етеді.

ДӨҢ шахтасының Алмаз-Жемчужина және Миллионное кенорындарының терең деңгейжиектеріндегі горизонттарындағы кенді жерасты тәсілімен қауіпсіз және тұрақты өндіріп алуды дамыту бойынша хромит қорларын аралас геотехнологиямен пысықтауға бағытталған өзекті мәселені шешуге арналған.

Түйін сөздер: қазу жүйесі, техногендік опырылу, жерасты технологиясы, хром өндіру, өздігінен құлау, сілем, тау-кен техникасы, тау-кен геологиялық жағдай, сілемнің геомеханикалық жағдайы.

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СОВРЕМЕННОЕ СОСТОЯНИЕ И ПЕРСПЕКТИВЫ УСТОЙЧИВОГО РАЗВИТИЯ ПОДЗЕМНОЙ ДОБЫЧИ ХРОМИТОВ НА НИЖНИХ ГОРИЗОНТАХ ШАХТ ДОНГОКА

Abstract. В статье рассматриваются вопросы современного состояния и перспективы развития подземных горных работ шах донских хромитов. С переходом горных работ на глубокие горизонты геомеханическая ситуация значительно осложняется, особенно для выработок днища блока, что предопределит необходимость решение вопросов по разработке мероприятий обеспечивающих повышение устойчивости выработок. Одним из наиболее радикальных мер является разработка конструкций искусственного днища блока, по принятому варианту систем разработки для нижних горизонтов шахты «Десять лет независимости Казахстана».

На основе анализа способов по созданию на горизонте выпуска и доставки искусственного днища к решению данной проблемы предлагается разработка конструкции с устойчивоопорной железобетонной платформой искусственного днища блоков из бетонно-твердеющей закладки, при системах этажного самообрушения руды, на горизонте выпуска и доставки используется как несущая конструкция элемента системы разработки, выдерживающие экстремально высокое горное давление, обеспечивающие повышенную устойчивость и надежность транспортных квершлагов, для доставки рудной массы с использованием самоходного оборудования. Направленное решение проблемы разработки актуально при отработке хромитовых запасов с комбинированной геотехнологией для безопасного и устойчивого развития подземной добычи руды на глубоких горизонтах месторождений Миллионное и Алмаз-Жемчужина шахты ДонГОКа.

Ключевые слова: система разработки, техногенные обрушения, подземная технология, добыча хрома, самообрушение, массив, горнорудная техника, горно-геологические условия, геомеханическое состояние массива.

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