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COMBINED GEOTECHNOLOGY: THE TRANSITION TO A NEW TECHNOLOGICAL SETUP

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The collection contains scientific and methodological foundations and practical solutions for the introduction of new technological setup of the mining industry in the development of solid mineral deposits by combined geo technologies. The materials give the theory development for the design and operation of mining systems in the transition to a new technological structure. The methodological foundations of the geomechanical substantiation of the parameters of combined geo technologies are presented. Particular attention is paid to design issues to ensure the stability of the faces and benches of quarries, cuts, dumps. The authors reveal innovative technical and technological solutions that are implemented in world practice to expand the mineral resource base, increase the completeness and complexity of the development of the subsoil.

The collection is of great interest to a wide range of specialists of industrial, scientific, design and educational organizations involved in the exploitation of mineral deposits.

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INTRODUCTION

For the sustainable development of the mining complex, the implementation of basic scientific research in the field of mining sciences, which entails the development of innovative products and services demanded by society not only now, but also in the future, acquires particular relevance. In this regard, the development of a theoretical basis for designing mining systems (mining enterprises) should be associated with the development of technologies that ensure the completeness and complexity of field development, resource conservation, effective reproduction of the mineral resource base and energy resources, reducing the negative impact of mining industries on the environment. To date, combined geo technologies to the greatest extent correspond to the principles of completeness and complexity of the development of solid mineral deposits. A combination of geo technologies is a combination of physical-technical and physical-chemical methods of extraction; means and methods of deposits development with technologies of formation and operation of man-made formations. The creation of combined geo technologies implies the development of sound principles of the phased and multifunctional use of the developed areas, the use of universal means of mechanization to work in various areas of the fields being explored. All this determines the increased interest in conducting research in the rock conditions and new principles of its management with combined geotechnology, methods of geomechanical monitoring, geological surveying measurements, quality management of mineral raw material flows, mining ecology. Therefore, the collection contains abstracts of reports of the 10th International Conference on the problems of combined geotechnology in the aspect of transition to a new technological structure.

The book considers the following problems:

- scientific and methodological foundations, practical solutions for the new technological setup introduction with a combined geotechnology;
- development of the theory of mining systems design and operation in the transition to a new technological setup;
-parameters geomechanical substantiation for combined geo technologies;
- innovative technological solutions;
- current aspects of the integrated and environmentally sound development of mineral resources and mineral processing;
- scientific and methodological and practical support for the stability of the faces and benches of quarries, opencast mines.

The fundamental scientific problems reflected in the theses of the conference participants include:

- the fundamental basis for the development of combined geotechnology in the transition to a new technological setup;
- regularities and stages of transition from open pit mining to underground mining methods. The principles of combining physico-technical and physico-chemical geo technologies in the area of mineral resources being mastered;

- the current state and stages of the formation of the open-underground method of developing ore deposits;

- design principles of mining systems when introducing a new technological setup;

- estimation features and basic principles for calculating the geomechanical state of mountain ranges with combined geotechnology;

- approaches to the development of projects from the early stages of exploration to construction and operation, used in world design practice;

- fundamental principles of safety of technological processes at the combined geo technologies;

- laws of geomechanical processes with a combination of various methods of extraction in a single technological area;

- legislative regulation of the rules for assessing and managing the stability of the faces and benches, quarries, mines and dumps with open and combined development of the field;

principles for assessing the environmental safety of mining production.

At the present stage, the development of the theoretical base for the design of combined geo technologies should correspond to progressive scientific ideas and technological innovations, which constitute the new technological setup, providing for the introduction of new systems and methods for developing fields, innovative mining equipment with elements of artificial intelligence, environmentally friendly mobile electrically-driven mountain vehicles, complexes and renewable energy systems, automated design systems, Equipment for interactive monitoring of the rock conditions and surface working-up areas online, innovative means of researching the properties, structure and rock conditions.

In this regard, the actual problems of the development of combined geo technologies are remote automated and robotic technologies for extracting solid minerals from the subsoil. This is a basic trend in all industries, and in the field of subsoil use, it determines special safety requirements for mining operations, production organization and culture while reducing occupational injuries and significantly improving the working conditions of miners. In this regard, regionalization of production areas of quarries and underground mines is promising, depending on the fact and frequency of human presence in dangerous areas of mining operations. Considering this, the requirements for design and mining operations in these zones should be differentiated. In the light of these prospects, the principles of the functioning of mining and transportation equipment with elements of artificial intelligence during its implementation at a mining enterprise, including at various stages of its operation, are determined. Particular attention is paid to the justification of the parameters of the opening schemes and development systems with the combined method of mastering the subsoil with machines and mechanisms equipped with elements of artificial intelligence.

A significant part of theses is devoted to the establishment of regularities of geomechanical processes that determine the effectiveness of the

implementation of combined geo technologies in the transition to a new technological setup, and among them:

- the fundamental laws of formation in the dynamics of the development of mining of the stress-strain state of rock mass in the transition period from one geotechnology to another when they are combined in space in limited areas;
- providing a controlled state of the mountain range, undermined by open and underground workings, exposed to gas, hydrodynamic and physicochemical processes and brought by mining operations in a state close to the limit for stability;
- driving and fixing workings with ensuring the stability of rock outcrops in the near-quarry massif with complex and non-monotonic changes in the strength characteristics and parameters of stress fields and deformations;
- creation of reliable isolation of underground workings from the quarry area to address issues of ventilation and drainage, prevent oxidative processes, storage of waste production and processing of mineral raw materials;
- construction of the excavating workings of an underground mine from the open pit mine space, section under conditions of increased dimensions of the zones of deformation of mountain ranges under the influence of open and underground mining

features of the assessment and monitoring of the geomechanical rock conditions during the extraction of reserves beyond the marginal contour of the quarry or mine, including with the use of combines or drilling equipment with intelligent control.

Solving these issues ensures the successful implementation of the processes of combined geotechnology, and hence the extension period for the longest possible period of effective development of the subsoil area due to the complex involvement in the operation of all types of geo resources, including those not directly related to the extraction of basic minerals. Due to the results of the studies already performed at the design stage, a forecast should be formed in terms of the possibilities of integrated development of various types of geo resources in the area under development through the introduction of new technical means and innovative geotechnological processes of combined geotechnology. Due to the transition to a new technological setup using modern means and design methods, it is possible to determine the type and parameters of applied geo technologies and their combinations in a specific period of the mining system operation. This makes it possible to predict the type and methods of controlling the volumes and quality of solid and liquid mineral and raw material flows generated at various stages of field exploitation. With a combination of physico-technical and physico-chemical geo technologies, the list and volume of commodity products obtained in the cycle of mining and processing production is expanded. Undoubtedly, combined geo technologies are an increase in the level of social responsibility for the adopted technological decisions, which require optimization of their parameters while ensuring the balance of technical, economic, ecological,

economic and social interests of the state, the subsoil user, and the population of the regions.

Most of the problems discussed in the collection are at the junction of scientific specialties. That is why modern technical and technological trends in the context of the development of mineral deposits with the combination of physico-technical and physico-chemical methods of mining in one section of the subsoil are of particular interest for subsoil users, specialists of design organizations and research institutes, universities and are the basis for the growth of the mining complex effectiveness.

SCIENTIFICALLY METHODICAL BASES, PRACTICAL SOLUTIONS FOR THE NEW TECHNOLOGICAL SETUP REALIZATION IN COMBINED GEOTECHNOLOGY

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COMBINED GEOTECHNOLOGIES AS A BASIS FOR THE TRANSITION TO THE NEW WAVE OF INNOVATION IN MINERAL RESOURCES MANAGEMENT*

The demand in georesources and ways of meeting it have always determined the style of social development. In this context the combined geotechnology is characterized by three periods of formation and development. The first period – geomechanical, is based on the evaluation of the parameters of stress fields and stability of mine structure elements in the design and planning of surface and underground mining method combinations. In this period, the studies are focused on fundamentally possible scenarios of combined mining depending on the thickness of ore deposits, surface mining philosophy and an open-pit depth, as well as mining methods used by an underground mine. The second period – geoengineering, is associated with a combination of mining processes in all their variety – from combined access and development of mine and open-pit takes with the use of advantages of both mining methods up to the application of equipment typical of one or another method of reserves development for stoping or face operations. New mineral mining flowsheets have appeared; standard mining engineering systems of combined geotechnology have been formed and classified. In this period, the backfilling technology has received a strong impetus for the development, at that, radically new options of mining of the reserves of a surface-underground horizon have been implemented on the basis of artificial roof-floor pillar formation between an open pit and an underground mine. New effects have been achieved, and earlier unknown objective relationships have been found in temperature and ventilation requirements, and extraction front advance principles. At the geoengineering stage of development, the prospects of the combination of physical-mechnical and physical-chemical methods of mining have been studied and estimated. The idea of "combined geotechnology" itself has been also formulated in this period. In terms of the application aspect, industrial safety rules have been elaborated, they determine the conditions of safety-in-mining for combined (integrated) mining of mineral deposits.

The third period is associated with the development of geotechnology as a basis of the transition to the new wave of innovation, when the combination of mining methods is the foundation for meeting of the society demand not only in georesources, as it is an inseparable part of mineral resources management, but also in safety, environmental wellbeing, social security. The new wave of innovation in mineral resources management is undoubtedly linked with the development of digital economy. The evolution of network communication (Internet) technologies and novel hardware, including that with artificial intelligence elements, software suites for geodata processing, high accuracy methods and facilities for the research into

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underground materials, as well as rock mass structure determine new areas of ore deposit development planning and design. All of this collectively provide on-line data reception and processing of any scope of information on the condition of elements of mine structure and mined-out areas, actual state of mine machinery, quality of mine mineral material flows, composition of the environment in mine workings, etc, that is, the new wave of innovation opens opportunities of prompt synchronous transformation of an underground area section, and adaptation of geotechnologies depending on the society demand in georesources.

Thus, the new wave of innovation is an assemblage and a priority order of processes providing the achievement of mineral resource management objectives at certain stages of the social development, and the combined geotechnology serves a basis for its formation.

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TRANSITION CONDITIONS TO THE NEW TECHNOLOGICAL SETUP FOR OF RUSSIAN MINING ENTERPRISES DEVELOPMENT

For all subsoil use entities, at present, mining is moving to a qualitatively new level [1], where various aspects of mineral resource extraction are integrated into a new technological setup, in which a mining enterprise equipped with automated robotic-controlled robotized equipment is a tool for sustainable development of society.

The condition for the transition to a new technological setup of the mining enterprise is a large-scale restructuring of production on an innovative and digital basis, with an increase in production capacity of the enterprise against the background of widespread depletion of stocks, changing and expanding the list of technological operations, processes and marketable products. Moreover, the parameters of the technologies that make up the new technological setup should be in the form of a single complex adapted to the specific conditions of the development of solid mineral deposits. Under adaptation is understood the operational synchronous transformation of technological processes to the properties and state of the technologically transformed subsoil area, taking into account the changing needs of society, even regardless of the direct goals of extracting minerals from the subsoil.

The introduction of a new technological setup should be based on expanding the scope of application of autonomous intelligent equipment, programmatically adaptable to changing the conditions of development of the field, each of which is unique in its basis. At the same time, the place of realization of technological processes should be as close as possible to the place of formation of the product of labor: the place of production of marketable products - to the place of formation of their mineral component - to the mining faces. This objective need stems from the fact that a new technological pattern is a way to a new level of energy supply of the mining

system [2]. At the present stage, energy costs that are not directly related to the release of marketable products (various losses, additional logistic costs, etc.) are considered unacceptable. At the same time, sources of energy generated during the implementation of technological processes during the movement of various kinds of material flow should be used to the maximum. It is important to note that the energy needs of the mining industry will continue to grow as robotization, the introduction of new methods of continuous monitoring of the state of mountain ranges with the use of electronic means, new means of organizing and dispatching production while increasing the volume of mineral production, constantly deteriorating natural quality.

It is the level of the species and the level of energy supply that always determined the technological mode of development of the society. Therefore, the main condition for the transition to a new technological setup is the search for and involvement of additional sources of energy [3-4] of natural, man-made and man-made origin. Alternative energy sources formed during the techno genic transformation of the subsurface and the implementation of geotechnological processes are:

- energy of miner hydraulic flows - drainage and filling mixtures;
- energy of destruction of the rock mass and release of the ore mass under the action of its own gravity;
- deformation energy of the lining under the action of gravity of the crushed rocks;
- free energy of the air flow;
- energy of gravity of heavy vehicles;
- energy recovery braking forces of vehicles;
- energy of heat exchange processes in the rock mass;
- energy of own and induced oscillations of a mountain massif.

Studying the conditions of transition to a new technological setup shows that only on the basis of the interrelation of intelligent technologies and new technology, including with elements of artificial intelligence, software systems for geo data processing, high-precision methods and means of studying the substance of the subsoil, the structure and state of mountain ranges, renewable energy , identifies new directions in the design of integrated development of ore deposits by combined geotechnology with high efficiency and completeness of extraction of all valuable components from mineral resources and raw materials produced.

The transition to a new technological setup is associated with the operative synchronous transformation of environmentally balanced geo technologies to the characteristics of the developed subsoil area, taking into account the needs of society in geological resources.

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CONCEPTUAL APPROACH TO THE ASSESSMENT AND MANAGEMENT OF ENVIRONMENTAL AND TECHNOLOGICAL SYSTEMS

With the depletion of reserves of developed deposits, the priority (and in some cases the only) source of mineral raw materials may be mining industry waste (man-made deposits). Such man-made objects represent a large reserve of raw materials for the extraction of metals and other useful components, but at the same time they are sources of environmental pollution. The negative impact on the environment is manifested in an area that is tens or more times larger than the area occupied by the waste. Significantly, the consequences of the negative impact on the environment can be neutralized by placing them safely and introducing effective low-waste technologies. As a result, a general approach has been developed to assess and manage the effects of production on environmental-technological systems (ETS).

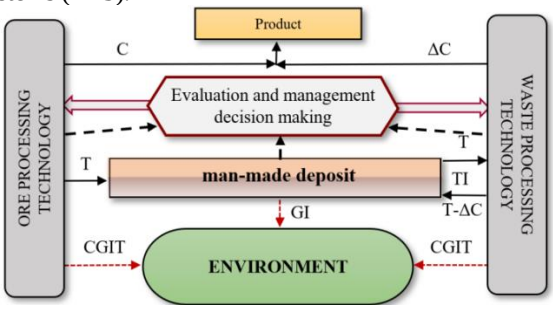

Figure – A conceptual approach to the assessment and management of environmental-technological systems: T– waste; C - valuable component; CGIT - a comprehensive geo-environmental indicator of technology; GI - geoecological indicators; TI - technological indicators

Thus, a conceptual approach to the formation of a management system has been proposed, considering the interrelation of technological and geo-ecological factors and depending on the type of production.

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STRATEGY FOR INTEGRATED DEVELOPMENT OF NATURAL AND TECHNO GENIC GEORESOURCES IN ZHEKKAZGAN REGION

The expansion of the mineral resource base on the basis of the integrated development of natural and man-made georesources is a priority for the development of Zhezkazgan mining region in the increasingly complex mining and geomechanical conditions [1-3]. This is possible due to the additional involvement in the operation of all types of copper-containing raw materials not previously involved in development — off-balance sheet and poor sulphide ores, ore reserves in the collapsed zones, various purposes, previously written off in losses, mixed and oxidized ores, and accumulated techno genic raw materials. At the same time, the rational development of these reserves will help stabilize the geomechanical situation in the region and have a beneficial effect on the environment by minimizing the deformations of the earth's surface and recycling mining and processing wastes. In addition, the complex involvement in the operation of poor natural and techno genic raw materials with the extraction of a wide range of valuable components will ensure the development of the regional economy and the employment of the population through the creation of new jobs.

At the stage of refining a large Zhezkazgan field, it is possible to compensate for the outgoing capacity only by bringing into operation, along with the remaining balance reserves, all poor ores and industrial raw materials, reserves in the pillars, collapse zones, laying, remote and previously written off in losses based on a fundamental change in the development geotechnologies sites of the field in accordance with the characteristics of the occurrence, geomechanical state and the material composition of the raw materials. For the conditions of the Zhezkazgan field, the introduction of innovative geotechnologies for ore extraction in previously lost pillars, in the zones of collapse, poor sulphide, oxidized and mixed ores and techno genic raw materials can extend the stable operation of the mining and processing complex for at least 40 years.

An audit of the resource potential of natural and man-made georesources in Zhezkazgan region allowed us to substantiate the economic assessment of the efficiency of technological schemes for the extraction and processing of each type of raw material in accordance with the occurrence conditions, geomechanical state and peculiarities of the material composition of multicomponent ores and techno genic raw materials [4].

The integrated development of natural and man-made georesources of Zhezkazgan region requires additional inclusion in the completed environmentally balanced cycle of the processes of physical and chemical geotechnologies and innovative hydrometallurgical processing with high through extraction of all valuable components and waste disposal [5].

A strategic approach to the integrated development of natural and man-made georesources of Zhezkazgan region with the replenishment of the raw material base is of major socio-economic importance, contributes to the extension of the life of mines with the preservation of production volumes and jobs.

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COMBINED MINING METHOD FOR SUSTAINABLE DEVELOPMENT OF DEEP CHROMITES MINING AT DON MINING AND PROCESSING PLANT MINES

In conditions of limited and irreplaceable mineral reserves in their development, the task of saving the riches of the subsoil resources becomes of particular importance, which requires the improvement and application of new variants of underground geotechnology.

With the development of the sewage works front in these conditions, the implementation of a large amount of mining and rifled workings, as well as the

creation of closed excavation areas, there is a need for more rational management of technological processes, ensuring reliable structural elements of the system for developing a selection of methods and means of securing mine workings to ensure efficient and safe mining system. This is achieved by dividing the developed deposits into areas with a mining front in staggered order within the horizon with a descending horizontal layered system, together with laying the developed space under artificial overlap and ore self-destructing technology to improve the efficiency of cleaning operations using combined underground geotechnology, ensuring rational development of reserves from the subsoil in deep ore deposits with a capacity of up to and more than 80 m and highly fractured and not stable ore reserves and enclosing rock massifs (sometimes in the form of a separate deposit).

One of this method advantages is to increase the economic efficiency of refining operations in deep and difficult-to-separate ore deposits with a capacity of up to 80 m, with highly fractured and unstable ore reserves and host rock masses, by reducing the cost of backfilling without degrading the marketable value of mining , with a combination of technology with self-rubbing of ore, by dividing the mined deposits into sections with the conduct of the mining front in a staggered manner within the floor, having the form block from a bookmark in the form of a trapezoid with an angle of inclination of the walls of the lateral borders of the block 70-80 ° from the upper filling layer at a depositional angle.

Technical and economic analysis showed the feasibility of the transition and the procedure for conducting cleaning work with combined geotechnology, where the annual production of an underground mine 1.0 million tons of chromite ore, the savings will be 183 million tenge.

All this will increase the trouble-free and safe operation of the field, reduce the cost of maintaining them and eliminate the cost of costly supporting works. This method is a combined development system for the sustainable development of the field deep chromite mining and can be used in the development of ore deposits of the Republic of Kazakhstan with similar mining and geological conditions.

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MODERNISATION PRACTICE OF MINING PROCESSES

In the last decade, the mining science department of OJSC Uralmekhanobr has successfully developed a direction that would seem to be not directly related to science, with fundamental scientific research - this is a technical re-equipment of existing mining enterprises.

The complex of measures to improve the technical and economic level of individual industries and sites based on the introduction of advanced technology and technology, the mechanization and automation of production, refers to the technical re-equipment of enterprises.

A great contribution to the scientific substantiation of the feasibility of technical re-equipment of mining enterprises was made by scientists: N. V. Melnikova, D. R. Kaplunov, M. V. Rylnikova, V. P. Mazikin, N. V. Shveiko, S. V. Kornilkov, G K. Ibraeva et al.

The purpose of technical re-equipment of existing enterprises is the intensification of production, an increase in production capacity and output. Improving its quality and cost reduction and improving the technical and economic performance of the enterprise as a whole.

To date, many existing mining companies have been working on projects that have been completed for twenty, thirty, and even fifty or more years. In order to rearm the enterprise in the framework of such a project is not easy. Yes, long-term projects are periodically reviewed, but the implementation of changes or additions to the current project is associated with large material and time costs, the obligatory passing through Glavgosexpertiza control.

Within the framework of existing projects for the construction and development of fields, existing enterprises have been offered to develop projects for technical re-equipment of basic mining processes, undergoing industrial safety expertise and registration with supervisory authorities.

Using the achievements of recent years, within the framework of the technical re-equipment project, the Department of Mining Science of the institute developed a number of existing enterprises for a number of existing enterprises. Their implementation made it possible to quickly transfer enterprises to new technologies and quickly retool mining production to a new, modern level.

Over the past 5 years, OJSC Uralmekhanobr, at the request of enterprises, has completed a number of technical re-equipment projects for mining companies in the Urals, Siberia and Yakutia.

OOO UMMK-Holding - 12 projects of technical re-equipment.

Underground mines: "Uzelginsky", "Youth", "Uchalinsky", "Lake", "Safyanovsky".

EVRAZ ZSMK JSC - 7 projects of technical re-equipment.

Underground mines: "Sheregesh", "Tashtagolsky").

SC ALROSA - 1 project of technical re-equipment.

Underground mine "Aikhalsk").

Evaluation of the results of technical re-equipment of mechanization technological processes and means at these mining enterprises makes it possible to draw a conclusion about the effectiveness of the chosen approach to solving the problems posed when developing individual sections of deposits. Increased production capacity, improved indicators of completeness of the reserves excavation and ensured the safety of mining operations.

According to the results of technical re-equipment performed by Uralmekhanobr JSC, two monographs were prepared for publication.

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MINING ENTERPRISE DEVELOPMENT BASED ON PRODUCT LINE DIVERSIFICATION

Modern mining enterprises are in a situation of intense competition, dynamic changes in prices and demand for the raw materials to be produced. This results in the constant search for more promising and progressive solutions that allow optimizing the available resources and available reserves to improve the production viability and efficiency. This is especially important for enterprises that are the basis of single-industry towns and settlements, whose social and economic position depends on the level of production development.

Often, many mining companies, in order to reduce costs in a number of technological processes, resort to outsourcing services provided by third-party organizations. On the basis of outsourcing, at present, the full development of a field is possible without having its own staff and equipment. At the same time, there is another approach to the management of enterprise resources based on the production diversification. Diversification is the extension of economic activity to new areas (expansion of the range of products, types of provided services, etc.). Based on the diversification of activities with technological and organizational changes that aim production at expanding the boundaries of the field of open geotechnologies, expanding the range of products and services, it is possible to increase the complexity of the development of the subsurface site and increase the viability of the enterprise. Diversification of mining enterprises can be done in three main aspects. The first direction involves the development of production in the technological production chain of final products with the expansion of its range on the basis of the extracted minerals. The second direction involves the production of a specific and unique production for mining - the formation and development of man-made georesources. The third direction is the supply on the market, characteristic for the main production, of various outsourcing services.

Creation of mining enterprises based on the model of optimal and balanced use of production diversification and outsourcing strategies taking into account the integrated development of natural and man-made georesources, with an expanded range of products and services that can flexibly change their production volumes and compete in the market due to their specificity and uniqueness, will increase efficiency of the subsoil plot development and ensure the sustainable development of enterprises in changing market conditions.

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HIGH-PERFORMANCE UNDERGROUND CLUSTERS OF MINERAL MINING BASED ON COMBINED GEOTECHNOLOGIES

In the current situation in mine planning and design it is important to choose the solutions, which provide high social adaptability of geotechnologies to the problems of mining regions while at the same time sustaining the positive momentum of financial flows. It is also important to achieve favorable environmental performance. Today, both in advanced world economies and in developing countries, mining operators encounter difficulties while getting social licenses, particularly in case of mineral deposit surface mining. In the future, with the inevitable growth of industrial production this challenge will become even more pressing, as mineral mining is expected to grow proportionally. For the conditions of deposit development it clearly indicates a multiplier effect on the tonnage of mined material with the respective environmental footprint. At deposits of the largest and oldest ore provinces of the Southern Urals copper-zinc pyrite ores with Cu, Zn cut-off grades of 0.5%, 0.8% respectively, and that of Au of 0.5 g/t have been already drawn into production. Clearly, tailing volumes will grow respectively.

High-performance underground clusters address these problems based on the combination of underground mining and leaching [1]. The research performed for the conditions of copper deposits development in the Southern Urals by chamber mining with solid stowing of mined-out areas has made it possible to identify the conditions of the application and parameters of technologies for in-mine pre-concentration of low-grade ore. The technology provides drawing of the product of the main stage of pre-concentration only, namely, commercial ore with Cu of 0.75% and even higher, and Zn of up to 1% for further flotation at a concentration plant. Two other products of the main stage of pre-concentration are waste rock and metal middlings. Waste rock is not drawn to the surface and can be used for stowing of mined-out areas. Solid stowing of mined-out areas is performed by underground mobile stowage facilities. Solid stowing of mined-out areas solves the problem of waste management and formation of the required processing areas of a “chamber-reactor” type, as well areas for paste filling of chambers with tailings. Middlings of the pre-concentration stage serves a feedstock for the leaching cycle. This process is implemented in the processing areas of an underground cluster, such as, “chamber-reactor” based on patent [2]. In these chambers, where the required conditions (temperature, oxygen content and solution feeding) are provided, the processes of chemical and/or bacterial leaching (the efficiency of the latter has been studied with indigenous microbial strains) of ore are implemented. Only pregnant leach solutions are pumped to the surface for comprehensive recovery of non-ferrous, rare and noble metals, and regeneration of solutions. High-performance clusters provide

for comprehensive development of a deposit: low-grade sulphide, complex and oxidized ores are drawn into production on the basis of new principles of reserves estimation; mine water is used in mining processes, and neoformed underground areas are efficiently used as an actual resource.

For the conditions of ore deposits in Russia it means the future gain of reserves of the deposits now being developed: 20% in terms of saleable product of platinum-group metals for the deposits developed by the Norilsk Nickel MMC; 35% in terms of saleable product (Dore bead and germanium) for gold deposits developed by UGC gold-mining company; at deposits developed by UMMC: 40 Mt for the Gai deposit, 15 Mt for the Novouchalinskoye deposit, 10-fold gain for the Oktyabrskoe deposit of the Buribaevsky GOK (56 of 64 ore bodies are estimated as cut-off grade ore). In the future, with the change of market situation and operation expenses, high-performance underground clusters on the basis of combined underground mining and leaching technologies will become an important component for the production of the required tonnages of primary metals.

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FUZZY LOGIC VALUE OF ENVIRONMENTAL RISKS IN OPENING COPPER-SULFIDE DEPOSITS

The development of copper-sulfide deposits inevitably leads to an intensive environmental impact, which is characterized by environmental risks. Reducing the overall reserves and quality of mineral raw materials, the imperfection of technologies for extracting valuable components from low-quality and poor ore contributes to the continuous accumulation of solid, liquid waste that adversely affect the ecosystem in the influence zone of mining and processing enterprises. Constant environmental risk evaluation is required at all stages of mining, enrichment and processing of copper-sulfide raw materials.

In our opinion, the environmental risk assessment system should be a subsystem of the enterprise's total generative planning system (GPS). Currently, various approaches are being applied to the very concept of environmental risk [1]. In the situation we are considering, it seems appropriate to use a combination of deterministic and non-fiscal approaches. Within the framework of a deterministic approach, knowledge bases are

formulated about processes not affected by poorly predictable factors [2, 3]. Within the framework of a fuzzy approach, knowledge of the processes affected by poorly formulated factors is formulated.

Thus, a hybrid system of environmental risk assessment is being created [4]. The subsystem formulates qualitative environmental risk values.

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ASSESSMENT OF PROSPECTS FOR CHANGES IN THE MINERAL RESOURCE BASE OF RUSSIA'S GEORESOURCES*

In recent years, various geological institutes completed a series of works on the current state of the Russia mineral resource base, the evaluation of the subsoil potential, and the mineral material and value balance. Only the profitable, competitive part of the mineral resource base (MRB), guaranteed to be in demand at a given time period, was involved in the calculations. The valuation corresponds to the period of its implementation. One of them is characterized by the ratio of $ 1 = 24 rubles. When this ratio changes, the results are adjusted.

It is possible to assess the degree of use of the explored base in kind through natural indicators. In physical terms, MRBs remain stable and change due to the growth of deposits that have been additionally explored or involved in the development. It becomes possible to compare explored and developed deposits. The change in this ratio in different periods determines the level of use of the country's overall minerals material potential. This principle underlies the consideration of five major resources by MRBs: diamonds, copper, nickel, lead, and iron. For each resource, a brief description of the existing MRBs is presented: the total number of deposits explored and transferred for development, their territorial location, availability of technogenic resources taken into account and their development prospects, taking into account new deposits introduced into development in the next 3-4 years. It is noted that geological exploration is carried

* Studies are conducted within the topic IPKON RAS 0138-2014-0001

out mainly by the mining companies. An example of the discovery of new deposits is given. A statement of compensation for the loss of reserves due to the increase in mining exploration is given.

The changes of the mentioned natural ratio for three periods: past, present and near future are determined, and the general changes in the MRBs of the mentioned georesources are systematized. The forecast of increasing the load on MRBs in the near future, registration of technogenic formations with their commissioning, with the increasing role of the environmental factor, returning to the undistributed fund previously transferred to subsoil users for the development of deposits is given.

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THE BASES FOR THE GEOTECHNOLOGICAL STRATEGY OF THE DEVELOPMENT OF TRANSITION ZONES OF ORE DEPOSITS BY THE UNDERGROUND METHOD

The problem of justifying the geo technological strategy of transition from open pit mining (OPM) to subsurface mining (SSM) is largely related to ensuring the safety and efficiency of developing transition zones (TZ). The purpose of the transition process in the combined development of the field is to transfer the mining enterprise from one stable state, corresponding to the normal stage of development of, to another, corresponding to the normal stage of SSM. Hence, the main purpose of the transition process can be considered as the creation of the most favorable conditions for an enterprise to achieve a stable state during the development of reserves at the normal stage of development of the SSM.

The characteristics of the transition process are: a sharp change in the value of the enterprise's performance, usually in the direction of its reduction, and a surge in the value of capital investments several times greater than their required value to maintain the production capacity of the enterprise during the stable period of the OPM. The result is a sharp decrease in the profitability of the mining enterprise during the transition period, which is also significantly affected by an increase in operating costs associated with the influence of negative specific factors.

The transition process in combined development has been defined as development (opening, clearing excavation and depreciation) of a part of a field in order to transfer the mining enterprise from one stable state to another; and the transition zone is a part of the field, within which organizational, technical and technological measures are taken, aimed at creating optimal conditions for the development of reserves in a stable period of the SSM, taking into account specific factors and conditions formed during the OPM.

TZ types are systematized; geotechnologies options have been developed that provide optimal conditions for SSM at a stable stage. On the basis of economic and mathematical modeling, the optimal variant of a

geotechnological strategy has been established according to the criteria of minimum reduction in the company's profitability during the transition period and maximum net discounted income from the development of all underground reserves under the underground method (TZ and main reserves).

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PROSPECTS OF PROCESSING AND DISPOSAL OF MINING WASTE IN THE NEW TECHNOLOGICAL ORDER

The problem of development of mining and metallurgical waste throughout the post-Soviet space is very relevant. Kyrgyzstan, during the period of joining the USSR, occupied a leading place in the production of antimony, mercury, coal, etc., and after the collapse of the Union for gold mining. As a result of intensive development of polymetallic and gold deposits in the territory of Kyrgyzstan, about 500 million tons of mining waste have been accumulated [1]. It's creating environmental danger not only in the territory of placement, but also for Kazakhstan, Uzbekistan, Tajikistan, the Republic of China. Through which territories flow trans - state rivers-Naryn, Syrdarya, Chui, etc., and contributing to the geochemical migration of harmful components. Therefore, the problem of processing and disposal of mining waste is becoming more relevant and in demand than ever. Provide deep processing of accumulated mining waste will allow a thorough mineral-analytical study of their material composition, technological properties by methods of technological Mineralogy.

Mining waste on the territory of Kyrgyzstan are divided into: coal and steel (cinders). In coal waste deposits Sulyukty, Kyzyl-Kiya, Abshir, Almalyk and other, by mineralogical research were detected high and sometimes sub-industrial levels of Ag, Pb, Zn, Sb, Hg. In addition to non-ferrous metals, the presence of P2O5 with a concentration of up to 11% and Al2O3 with a content of 29.3% was established. These researches allow us to consider the coal waste of Kyrgyzstan as a promising raw material for the extraction of heavy non-ferrous metals, as an aluminum raw material, as well as a promising raw material for the production of phosphorus fertilizers.

Huge amounts of metallurgical slag, a waste product (tens of millions of tons) accumulated in areas of mercury deposits mills (Khaidarkan, Chauvay, Tootoo, etc.) are characterized by a high content of silica up to 8-10 %, and cinder deposits, in Outoo a high content of magnesia. The perspective of processing of siliceous scoria is using it in the manufacture of cement. Magnesite slag, a waste product can be used in the manufacture of refractory bricks.

Mineralogical researches of samples from the dumps of mining and processing of polymetallic ores (deposits of Kan-I-Gut, Kan) found an increased content of silver and a number of rare earth metals, which could be detected due to the integration of mineral analytical methods. The intensive development of nanotechnology methods and their application in investigated regions can expand the prospects of processing of mining, ore mining, and metallurgical waste.

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COMPLEX NON-TYPICAL SOLUTIONS OF ROCK REFUSE DECOMMISSIONING

To date, in the territory of the Russian Federation many tailing dumps are practically in a limiting position, while, as a result of the deposits mining by the open method, a significant amount of open pit mine has been accumulated. No less urgent problem is the reclamation of all lands disturbed by mining.

A comprehensive solution to these problems is possible when receiving from the enrichment waste products suitable for the reclamation of the developed spaces. This approach allows reducing the environmental load in the field of mining by eliminating the alienation of new land for the construction of new tailings with simultaneous reclamation of spent quarries achieving economic benefits when this is achieved by reducing the capital costs of preparing storage sites and reducing environmental charges.

The formation of hydro-resistant massifs, which prevent undesirable elements from filtering into aquifers, in the bed of storage sites is carried out from products obtained from tailings in the process of paste condensation or condensation of high density. In some cases, for example, during the formation of anti-filtration screens from diamond mining waste, additional regrinding of the material may be required due to its considerable size. At the same time, to obtain products for the reclamation of gold ores from waste products, it is sufficient to thicken the products using polymers to a high density, without obtaining paste products.

For various types of enrichment wastes, the specialists of OOO UralGeoProject carried out a range of activities, including:

- research works
- laboratory tests

- pilot testing
- development of process schedules
- conducting a feasibility study of the proposed technologies.

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ON THE CREATION OF A TECHNOLOGICAL COMPETENCE CENTER IN RUSSIA IN THE WASTE MANAGEMENT FIELD OF MINING ENTERPRISES

The current state of the mining and metallurgical complex of the Russian Federation is characterized by a decrease in investment in geological exploration projects compared to the scale achieved during the Soviet era, on the other hand, an increase in the production capacity of enterprises and an increase in the efficiency of technology.

The result is a shortage of mineral resources and a decrease in the quality of minerals involved in mining and processing. This is what determines the wide development of combined geotechnologies, which allow significantly expanding the raw material base and ensuring the required volumes of extraction of mineral raw materials [1, 2].

In addition, a significant negative factor in the activities of mining and metallurgical complexes is still the storage and accumulation of industrial waste - overburden, off-balance and oxidized ores, ore dressing tailings, cinder, ashes and slags and other types of technogenic raw materials [3]. Conventionally, mining waste is divided into two main groups: mining waste, represented by lumpy material from mining operations and enrichment waste.

Since at each mining enterprise the volume of overburden and substandard ores is several times higher than the balance reserves of ores, the priority is to develop a database on the capabilities and indicators of ore flow quality management technologies through preliminary mine separation with substantiation of process parameters. When selecting pre-beneficiation schemes at the planning stage, the additional CAPEX for mining equipment and mining costs associated with the mining of poor and substandard ores, previously attributed to off-balance, with a concomitant stripping ratio, should be taken into account in calculating the economic efficiency. Waste enrichment is of industrial interest due to the fact that it is already mined material extracted from the depths, and therefore the cost of additional enrichment using new technologies is lower than the processing of ordinary ore - according to world experience on average by 25-50%.

It should be emphasized that so far in Russia there are no mechanisms that would ensure the widespread dissemination of efficient waste management technologies to produce marketable products. In order to solve this problem, we need:

- development of a mechanism for simplified putting on the balance of technogenic deposits (for example, with placer technogenic objects);

- creation and development of experience in the implementation of technologies for the exploration and study of the structure of technogenic deposits;

- development of technologies for the extraction of raw materials of technogenic formations and its environmentally safe transportation;

- creation of effective technological schemes for processing of technogenic raw materials.

Successful solution of these problems significantly affects the final cost and profit from this kind of mining activity. In this regard, the new technological order of development of the mining industry should be the direction associated with waste management on the basis of combined geotechnologies.

In Russia, it is necessary to create a competence center for the development of technologies for the extraction and processing of waste from mining and metallurgical enterprises. The main purpose of its creation is the accumulation of the information base on technologies and models for creating a ready-made solution for the development of man-made objects in a given time frame. Despite the uniqueness of each technogenic object, the base creation for technical and technological solutions for the rapid testing and adaptation of technologies for the commissioning of various types of mineral resources will contribute to the development of a waste management system in our country.

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TRAINING PECULIARITIES OF MINING ENGINEERS' AND WORKERS' WHEN PASSING TO A NEW TECHNOLOGICAL PARADIGM

The implementation pace of cyber-physical systems in the production and accumulation of the development potential of such new areas as robotics, nano- and biotechnology, artificial intelligence, the Internet of things allows us to talk about the transition to a new technological paradigm. It is predicted that this will radically change not only economic, technological, political, but also

social systems. Technological changes can not affect the development of institutions of public life, among which one of the most important is the institute of education.

Transformation of economy sectors, increasing transparency and accessibility of information, new principles of digital reality – all this requires workers with appropriate training, able to interact with high-tech and software production, with artificial intelligence, have completely new qualities and competencies. And for the first time, workers entering the labour market and workers with experience should master the necessary volume of ever faster and more complex theoretical and practical knowledge. Each employee must receive the necessary knowledge in order to become a highly qualified specialist in his chosen profession. The challenge of the forthcoming fourth industrial revolution and the accelerating scientific and technological progress is the accessibility of education for every citizen. In the context of the future replacement of a number of specialists by self-learning software, robots and machines, as well as the disappearance of old professions, as many people as possible should have access to improve their skills, develop and master new knowledge and competencies.

The importance of digital skills for work and social integration is increasing. The level of such skills possession will determine the success of a person's life and employment prospects. According to experts' opinion, 65% of today's students of schools and university students will do work that does not yet exist. But it is already clear that a significant number of employees with digital competencies at different levels in the company will provide it with a competitive advantage.

For several decades, there has been a discussion about how to prepare a specialist in an educational institution who fully meets the employer's needs. A national system of qualifications is currently being formed in Russia, its key elements being professional standards. Professional standards express a consolidated view of the professional community about the features of a particular type of professional activity and allow building a dialogue between two parties - the vocational education system and employers. Changes in the qualifications system created an unprecedented situation for the system of personnel training. A few years ago, vocational education could quite successfully exist as a closed system, the goals and development priorities of which were established primarily on the basis of the internal needs and interests of the scientific and pedagogical community, but today this practice is impossible. Only a direct link with the economy, a real-time response to signals from the labour market, will allow specialists to be trained by employers. The answer to this request will be the creation of ecosystems, including public and private educational organizations, business representatives and other employers, industry groups, professional communities.

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DEVELOPMENT OF THE GEOMECHANICAL MONITORING METHODS FOR THE MINING AND TECHNOGENIC MASSIF STATE DURING THE TRANSITION TO A NEW TECHNOLOGICAL SETUP

At the present stage of scientific and technological progress, the increase in the efficiency of open-cast mining depends to a decisive extent on the expansion of the field of application of combined geotechnologies, the introduction of open geotechnologies with intelligent mining and transport equipment and automated mining control systems, robotic mining technology complexes based on high-tech telecommunications innovations, navigation, radio physics [1-3].

At the same time, there is a significant reduction in the risk factor of the presence of a person in the hazardous area of mining operations with an increase in the intensity of mining, which leads to the development of a new technological mode of mining production.

Already now, the choice of the safety factor of the boards, their sections, working and non-working ledges of the quarry, as well as the dumps is carried out taking into account the stage of development of the field, which determines the degree of reliability of the initial data and timing of standing slopes, differentially along the ledges and sections of the open pit walls. In this regard, on the deep horizons of the quarry, the priority of ensuring safety and improving the reliability of achieving the indicators of open geotechnologies is the development of methods for geomechanical monitoring of the mountain massif state near the developed quarry space [4].

Changes in the geotechnologies parameters in the transition to intelligent systems with a concomitant increase in possible risks require the improvement of monitoring technologies for the state of mining structures and mining systems in general.

Creation of monitoring systems using satellite navigation, modern methods of ground-to-air laser scanning, software and hardware systems based on unmanned aerial vehicles, aerospace methods of GPR surveys with the construction of digital orthophotomaps and three-dimensional terrain models gives a unique opportunity to quickly and accurately determine spatial and temporal changes in volume -qualitative characteristics of the state of natural and man-made structures, the values of angular and linear deformations and movements that determine the intensity of natural and man-made geomechanical processes [5-7].

Based on the results of the monitoring of the stability of the sides, ledges and dumps, taking into account the results of the structural survey of the array, conducted in the process of mining, additional measures are being developed to manage the stability of slopes during the construction, operation and between the quarry reconstruction phases.

Such a development of the geomechanical monitoring system reduces the risk of exploitation, primarily of the deep horizons of the quarry, and allows the design of open pit walls with steeper slope slopes. It was this that was guided by ICEMR RAS when equipping with modern high-tech research equipment that allows timely obtaining reliable and detailed information about the state of the rock mass and mining system as a whole, the laboratory of environmentally balanced exploitation of the subsoil [8].

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JUSTIFICATION OF THE DYNAMICS PARAMETERS CHANGES OPENING-UP OF AN OPENCAST SYSTEM DURING TRANSITION PERIODS

Mining enterprises operate in a dynamic environment factors of external and internal environment. The development of steep deposits occurs, as a rule, over long periods of several decades. During this period, the external and internal factors in the operation of quarries change: the situation on commodity markets changes, the reserves and quality of mineral resources at the field are refined, new types of equipment are developed, etc. As a result of changes in these factors, the company revises the parameters of the current stages of the open-cast, make reconstruction, move to the combined open-underground method of development. Changes that occur in the enterprise during the transition to a new stage or method of development take place during certain periods - transitional periods. The decision to move to a new stage or method of development is based on a feasibility study of possible options. This is a rather complicated, time-consuming and responsible task, the solution of which is to analyze a large number of technical, technological and other factors.

Analysis of the theory and practice of development of steeply dipping fields showed that the development system at the field for the given mining and engineering conditions is practically unchangeable, and its parameters are regulated in a limited range, while the system for opening its parameters can differ significantly in development stages. The structure of the opening system should take into account the costs not only of penetration and equipment of the opening workings, but also the capital and operating costs of transport. Therefore, when analyzing the feasibility of the parameters of the transition period, the system of opening, its parameters and indicators will be crucial. The parameters of the opening-up of an opencast system affect the design of the working, temporary non-working and non-working pit walls, which in turn affects the average and current stripping ratio and, accordingly, capital and operating costs. When switching from one method of development to another, the parameters of the open pit system formed in a mine largely determine the technological capabilities and economic indicators of the construction and operation of an underground mine at the deposit when using a pit to deliver the ore to the surface. The dynamics of changes in the parameters of the opening-up of an opencast system determines the duration of the development stages, the timeliness of implementation and implementation of individual transformations of the opening-up of an opencast system at the mining enterprise, and the final indicators of the new development stage.

THEORY DEVELOPMENT OF MINING-TECHNICAL SYSTEM DESIGN AND FUNCTION IN THE TRANSITION TO A NEW TECHNOLOGICAL SETUP

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PECULIARITIES OF ENSURING SAFETY MINING AT GOREVSK DEPOSIT

Gorevsk deposit of lead-zinc ores is unique in terms of metal reserves and ore quality. It accounts for over 42% of all-Russian lead reserves. Industrial exploitation of the field began about 20 years ago and outlined a set of features that must be taken into account when solving the tasks of its development, namely: climatic conditions - the area is equated to the Far North; finding the deposit directly on the bank of the Angara River, with a part of the ore bodies going under the river bed; planned increase in the depth of the pit to 500 meters; introduction in parallel with the open underground method of ore mining; the presence of the created protective dam, which pushed Angara almost three hundred meters away; preparation of the construction of the second stage of the dam, which will move the river as far as 1 km; location of the field in a unique natural area; close location of urban settlements. These features imply a new formulation of tasks to ensure safe mining operations based on the assessment of the development of water filtration in the pit and changes in the geomechanical state of the water protection dam as the pit deepens, as well as monitoring the movement of the rock mass. A comprehensive study of these issues will allow expanding the scientific basis for the safe mining of the deposit in a combined way.

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THE MINE-TECHNICAL SYSTEM DESIGN PRINCIPLES OF RE-GEOTECHNOLOGY IN SUSTAINABLE DEVELOPMENT OF NEW-STYLE FOR CAVED DEPOSITS UNDERGROUND MINING AT ZHEZKAZGAN MINE

The report outlines the principles of re-geotechnology design when developing reserves in the conditions of caved deposits of Zhezkazgan field for the rational management of underground mining technological processes, which is an essential principle of the re-geotechnology mining system design on which the practice of designing and operating the subsoil section is developed during the development of mineral deposits. When designing a mining system with re-geotechnology for the development of caved reserves of subsurface, the risks and consequences of natural and man-made emergencies are taken into account. In modern conditions, mining design cannot function in isolation from the principles of sustainable development, which should be understood not only as a classical definition, implying such a development that ensures the existence of society without threatening future generations to meet their needs.

In this regard, the ongoing research covers the design of mining systems, considering the principles of sustainable development, which correspond to the priority current direction in the development of re-geotechnology of new style for the sustainable development of re-underground mining of reserves in the conditions of caved deposits of Zhezkazgan field.

The adopted testing schemes allow using a complex of high-performance mobile equipment in all technological processes. Cleaning work includes the sequence of technological processes such as drilling, loading and blasting wells, airing (during the inter-shift break), loading and hauling operations.

Issues of designing the structural elements of the rock bottom of the block, for the release of ore reserves from caved deposits for the design of the mining system of re-geotechnology with self-breaking of ore involves solving technical and economic problems to justify the optimal parameters of the technological system in the following directions:

- methodological substantiation of the content and structure of rationality of made decisions;

- geotechnological choice of the method of field re-development or part thereof; substantiation of the optimal technologies of the underground method of developing their application in the mine under study; justification of

technological schemes and parameters for the preparation and development of individual blocks in the conditions of caved deposits of copper ore deposits;

- feasibility study of the profitability of development and profitability, quantitative and qualitative characteristics of the products obtained from the proposed technology during the re-mining of reserves in the conditions of the caved area by the underground method on the example of Zhezkazgan mine.

All this becomes possible in modern conditions - safe, economic, technological, environmental and socially effective management using adaptive high re-geotechnologies, not so much for mining, but for the purpose of operating each developed area of he subsoil for an indefinite time, through initial design stages, through the transition from one type of geotechnology to another during the development of deposits, as well as for the period after the completion of mineral extraction. This approach is the content of a sustainable development format for the re-mining of the caved deposits of Zhezkazgan deposit by the underground mines of Kazakhmys Corporation LLP, which is one of the largest in the world in copper mining.

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DESIGN PRINCIPLES FOR MINING AND TECHNICAL SYSTEMS IN THE NEW TECHNOLOGICAL SETUP IMPLEMENTATION

The technological structure of mining production is understood as a set of associated geo technological processes that have a systemically integrated technical and technological level and are simultaneously developing [1]. The new technological structure of the mining enterprise is an intellectual, holistic and preferably sustainable education, within which a full cycle of exploration is carried out, starting with exploration, extraction and obtaining of primary mineral resources and ending with the release of end products and services set that meet the requirements of public consumption. The higher the degree of readiness of commodity products for consumption is, the higher the level of production profitability. The higher the level of technological structure is, the higher the degree of mechanization, automation, robotization and intelligence production.

The need to move to a new technological setup with a high level of mechanization, automation and intelligence production is associated with:

- the exhaustion of the traditional mineral resource base available to humanity 10 years ago, due to the long-term implementation of the concept of extensive subsoil use;
- the ubiquitous development of combined geo technologies, without which it is impossible to develop deposits in modern conditions;
- the consent of the world community on the transition to the principles of sustainable development of nature and society (the Paris Agreement governing measures to reduce carbon dioxide in the atmosphere from 2020 instead of the Kyoto Protocol), etc.

The main condition for the transition to a new technological setup is the development and introduction of new technological solutions that were not previously characteristic of traditional geo technological processes, or the consideration of known processes in a new capacity. The inclusion of combined geo technologies in the mining system, the transfer to the underground space of equipment that previously worked only in surface complexes, the immediate extraction of valuable components and the production of marketable products in underground conditions with the disposal of industrial waste into the developed space of the subsurface in the 21st century processes. This led to the transformation of basic concepts and definitions in mining. Thus, the “Underground Mining System” in the 20th century was represented as “... the order and sequence of preparatory-rifled and clearing workings carried out in time and space”. These processes at that time were the most time consuming and determined the overall intensity of the development of mining operations. At the beginning of the 21st century, this concept is considered as "... the totality and sequence of implementation of an expanded spectrum of basic and auxiliary technological processes used in a specific design for extracting reserves of an elementary excavation unit of a developed subsoil plot."

Therefore, the basic principles for the design of mining and technical systems when introducing a new technological setup are:

- intellectualization and robotization of the main and auxiliary technological processes [2];
- greening production and large-scale introduction of "green" technologies [3];
- a new type of organization and control of process parameters with risk assessment and information dissemination in real time;
- resource and energy saving and reproduction.

The transformation of the role and features of designing systems for developing ore deposits, a combination of geo technologies, determines that at the current stage of technical re-equipment of mines an expansion of the list of technological processes should be provided in order to obtain the best quantitative and qualitative indicators of subsoil development through the introduction of rational combinations of physical-technical and physical - chemical geo technological processes at the stages of mining and processing of mineral raw materials with their approach to the place of treating the mineral component from the interior to obtain a spread spectrum marketable products.

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PRINCIPAL APPROACHES TO THE DESIGN OF MINING-TECHNICAL SYSTEMS FOR UNDERGROUND DEVELOPMENT OF ORE DEPOSITS

The current state of mining in underground mines and the problems arising in the mining process determine the development of the design theory in terms of simplifying and unifying existing computational methods. This principle will allow mining engineers and other specialists of the subject area to determine quickly and accurately the design and technological parameters of underground mining engineering systems at all stages of research and development and survey work. The calculation mechanism for obtaining the necessary calculation data, in the opinion of the authors of the article, must contain a minimum number of parameters, the determination of which requires long and laborious empirical studies. And also, in the event of any changes in the production conditions, not to hinder the on-line adjustment of the working documentation by the engineering and technical personnel of the mining enterprise, in order to effectively adapt geo technologies to specific situations. The problem of the diversity of approaches to the definition of rational parameters of technology is particularly acute, stands when designing systems with the collapse of ore and host rocks. Incorrectly established parameters of these systems entail high losses of minerals, reduced quality of the mined ore, additional costs for enrichment, environmental degradation and, as a result, inefficient use of the subsoil.

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PARAMETERS AND CHARACTERISTICS OF THE DANGEROUS ZONES UNDER THE BOTTOM OF WASTE PITS, FLOODED WORKINGS AND DISCHARGE OF AQUIFERS DURING THE DEVELOPMENT OF KIMBERLITE DEPOSITS IN YAKUTIA

One of the necessary conditions for minimizing accidents and catastrophic cases in the extraction of minerals is the identification of potential geomechanical risks and timely adoption of security measures. A particularly urgent need for this is in the fields developed by the combined method, where the complex geomechanical situation is aggravated by the presence of high-pressure aquifers, flooded mine workings and accumulated water-saturated talus at the bottom of the quarries. In the conditions of kimberlite deposits of Yakutia, an additional complicating factor is the presence of powerful salt thicknesses in the host rocks.

Analysis of methodological and regulatory framework has led to the conclusion about the absence of methods of calculation of parameters of the pillars and danger zones in full compliance with the conditions of the development of kimberlite deposits.

In the course of the research identified sources of geomechanical risks for the combined method development and analyzed their formation mechanisms, and also highlights the typical danger zone for different stages of mining operations. Shows the need for an integrated method of calculation of parameters of dangerous zones, including methods of mathematical modeling of stress-strain state and evaluation of the geological and structural framework of the array and the influence of technological factors on the development of the processes of displacement, deformation and destruction of natural and artificial arrays.

Based on the developed methodological framework the parameters of dangerous zones and to formulate requirements for mining operations for the mining of sub-pit reserves and deep horizons of the mine "Internatsionalny". The zones of influence of flooded mine workings of the underground mine "Mir" are defined and the parameters of hazardous zones and safety targets for the stages of construction and development of reserves of the new mine to the full depth of explored reserves to a depth of 1700 meters are calculated.

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BASIS FOR MAIN RUNAWAYS PARAMETERS INCREASING OVERALL END-SLOPES AT OPEN-CASTS

The efficiency of mining operations, especially in steeply dipping fields, at the finalization stage depends primarily on the used mining equipment, the depth of the quarry and the height of the formed dumps. The cost of transportation in these conditions can reach 80% of the total cost of moving the mined rock mass, the movement of which by dump trucks is carried out by creating drive wheels' tangential traction force, which in turn is determined by the power, torque developed by the engine, gear ratio and rolling radius. Taking into account the recommended typical normative values of the longitudinal slope of the career roads, varying in the range of 80 ‰ -120‰, the length of capital trenches is estimated at several kilometres. The specified values of the guiding slopes are due to the optimal ratio of two factors: the load on the engine and the transmission of the dump truck and tire wear. It should be noted that these values were established considering the level of development of domestic engineering in those years.

To date, the current regulatory documentation regulates the maximum value of the longitudinal slope equal to the value recommended by the manufacturer. Modern quarry articulated dump trucks with wheel formula 4X4 are able to overcome inclines up to 240. In this case, the limiting factor is already the road conditions that cause the adhesion of the wheels to the road, as well as the energy aimed at overcoming the inertia force.

One of the promising ways to improve the efficiency of the transportation process in open pits is the organization of a traffic scheme in which the dump truck will spend the minimum amount of energy on long lifts. It is in conditions of prolonged ascents that the bulk of the energy falls on overcoming inertia forces.

In this regard, a change in the design of capital congresses with the allocation of areas with zero slope, as well as a bias close to that recommended by the dump truck manufacturer, taking into account road conditions, provides a reduction in only the costs of moving the rock mass account of the increase in the resulting longitudinal slope.

Thus, the combination of horizontal sites and areas with a maximum slope under the conditions of starting the dump truck provides a twofold increase in the steering slope of the main trenches, without increasing the cost of moving the rock mass, compared to the values adopted today in the practice of quarrying. This, when carrying out a transport link between horizons, provides

such an organization of a traffic pattern, in which the inertial forces in a horizontal section will have a positive effect on overcoming resistances to the movement of a dump truck in an ascent.

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THE INNOVATIVE TECHNOLOGY OF STRIPPING AND MINING OF DEEP KIMBERLITE OPEN PITS

At present, the problem of refining the legitimate ore reserves of diamond ore deposits lying below the limit boundaries of quarries, where the use of traditional technologies is economically inefficient, needs to be solved. The proposed innovative technology of open development of kimberlite deposits with variable geometry of non-working sides of the quarry allows to solve this problem.

The implementation of the technology is considered on the example of the development of the Nurbinsky quarry of ALROSA to a depth of 750 m, corresponding to the depth of the explored reserves. The technology includes two stages: the transition at a depth of 370 m from the traditional scheme of opening to the scheme of opening by steep-inclined road trains (21 – 25 %) using four-wheel drive articulated dump trucks with a capacity of 41 t and the transition at a depth of 530 m to the opening of the automobile tunnels passing behind. The main parameters of innovative technology in comparison with traditional technologies of development are given. Formulas for calculation of depth of transition to the new scheme of opening are offered. The innovative technology allows to increase the angles of slopes of the quarry sides from 45-48° in the upper zone to 57-75° in the lower, to reduce the volume of excavation of the overburden by 3-8 times and to effectively Refine the reserves of minerals. The method of calculation of the necessary speed of tunneling, taking into account the speed of the pit deepening, the slope of

roads, the vertical distance between the portals, the slope angles of the working and non-working sides of the quarry and the direction of the deepening.

According to preliminary estimates, the economic effect of the introduction of the technology at the ALROSA quarries will amount to 13.7 billion rubles. the proposed technology can be used not only in the development of kimberlite quarries, but also in the open development of deposits of non-ferrous and precious metals represented by steep-falling deposits of round shape.

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PROCESS MONITORING OF PLACING UNDERFLOW IN THE QUARRY AND UNDERGROUND MINE WORKED-OUT AREA FOR THE OPTIMIZATION OF THE SILL PILLAR FORMATION TECHNOLOGY AND FOR WORK SAFETY INSURANCE

Monitoring of the placing process for the condensed product in the open pit and underground mine of OOO Uchalinsky MPP was carried out according to the schedule and was aimed at assessing the volume of water inflow into the underground mine, the state of jumpers of all types (horizontal and vertical) and drainage wells, working out working horizons to identify the flow paths of the filtrate and the distribution of the pulp, water collectors, sludge debris, equipment of the pumping station and pressure pipeline, slurry pipeline, feeding the pulp from the thickener to the quarry, the level of the pond in the pit bowl, deformations of the earth's surface adjacent to the western and southern sides of the pit, the density, moisture content of the condensed product fed into the pit bowl and the particle size distribution of the original tailings and developing, in case of violation of the storage process, correcting events.

The following technical and technological materials were investigated to perform the work: design, executive and surveying documentation for filling the open pit and underground mine, the results of tests of the product stored in the quarry space, both at the production stage and from the locations at different time intervals (sampling frequency at least 2 times a month).

Based on the monitoring results for 2018, the following conclusions and recommendations were made:

1. In the course of pilot-industrial tests of storage of a condensed product on board the Uchalinsky open-pit mine, in order to investigate the properties of the paste product produced on the thickening complex, samples were taken and tested to determine humidity, rheological characteristics, solid to liquid ratio,

mixture density, and also calculated the speed of the pulp through the berms. The properties of the condensed product correspond to the design solutions.

2. For compiling the water balance, the method of measuring the volume of water inflow from the incoming pulp to the underground mine was used - for 2018, it amounts to 789,127 thousand m^3.

3. Inspection of concrete waterproofing jumpers showed that their condition was assessed as satisfactory, integrity violations were not recorded. At the construction stage it was a pleasure to decide to equip these facilities with water transfer devices.

4. The construction of an additional jumper 480/1 ensured safe mining operations on the lower horizons.

5. A survey of the mine horizons. Production, above the mountains. 460 m, filled with hardening bookmark, in the workings below the mountains. At 460 m, areas of pulp penetration into the existing mines were identified, and at present pulp flow routes have been eliminated.

6. Slag collectors and water collectors were examined; these objects operate in the normal mode.

7. It has been established that at present when storing pulp in the quarry space, the backfilling material with the addition of cement does not enter the underground workings, and therefore there is an increase in the volume of condensed product in the quarry, the formation of the pond zone in the quarry is not observed.

8. The absence of migration of condensed tailings into underground mine workings allows us to conclude that all underground cavities are filled. The total volume of backfilling work amounted to 1172784 m^3 and further storage of low-strength bookmarks is impractical.

9. An assessment of the state of the side surface indicates that there is no deformation during the storage of the condensed product.

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FEASIBILITY OF CREATING NATURE-LIKE MINING TECHNOLOGIES

The review of the current research activities aimed at finding methods and ways of preserving the Earth under vigorous extraction of mineral resources from lithosphere has guided the scientific problem formulation as fundamental application-oriented research for creation of nature-like and convergent technologies of mining solid minerals of different types and geology. The scale of the fundamental problem under solution is provided by the fact that the substance for construction of all elements of technosphere is and will be taken out of the Earth's lithosphere by means of solid mineral mining.

The general methodology of the set problem solution is characterized as creation of convergent mining technologies subject to preservation of biota of natural ecosystems disturbed by mining.

The variants of a convergent technology are simulated for underground mining of rock salt using honeycomb mine structures and kimberlite ore extraction using frame mine structures.

The scope of the analysis embraces two alternatives of stable honeycomb structures in mines: (1) fully-mechanized top-downward vertical excavation; (2) top-downward excavation with mechanized reaming of rat hole to serve as bypass.

The other idea consists in the early isolation of the man-made damage zone from the total field of secondary geophysical variations of the lithosphere by means of separating in time the processes of mineral mining and the processes of coping with geomechanical disturbance after-effects in adjacent rock mass. This idea has been materialized in the frame convergent geotechnology. Advance formation of the external boundary of an extraction area (block, stope) offers cardinally new capabilities of stoping method selection irrespective of the field of secondary geophysical variations in rock mass. The concept of the frame variant of the convergent mining technologies can be formulated as: cardinally new capabilities of improved safety and efficiency through purposeful technological convergence of different known methods in space and time.

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GEOMECHANICAL SUBSTANTIATION OF PARAMETERS OF HIGH DUMPS AND COMPLEX NATURAL-TECHNICAL SYSTEMS IN KUZBASS

The relevance of performed studies is confirmed by the shortage of areas for external dumps in Kuzbass with an increase in annual overburden volumes, reached 1.5 billion m^3 in 2018.One possible solution to this problem is to increase the height of the existing dumps. Another is dumping overburden onto the surface of hydraulic dumps, thus forming a complex natural-technical systems (NTS) "hydraulic dump + dump".The heights of these structures have already reached100-160 m, andsomeprojectsprovide their increase to 300 m and even 500 m. To determine the maximum parameters of dumps and NTS "dump + hydraulic dump", the authors use the developed geotechnical safety control system [2, 4], which includes a set of works in three areas: geological-engineering investigations, geomechanical substantiation and safety monitoring. The main requirement for investigations is compliance with the actual loads in determining the strength parametersand water properties of

rocks and soils. It is achieved by using original equipment and methods of conducting experiments. The dependences of the change in properties, which are used in the calculations, are already obtained in the load range of 0.05–5 MPa[2]. The threshold values of the filtration coefficient of technogenic rocks, at which the technogenic aquifer is formed in the dumps, are also established. The obtainednonlinear regularities of properties changes were used to substantiate geomechanical models, stability calculations, and numerical simulation of stress-strain state of the rock massif in Lagrangian and Eulerian formulation. The first was used to predict excess pore pressure, and the second was used to predict the penetration-replacement depth during the formation of embankments on a weak basis [1, 3, 4]. Ensuring the safety formation of high dumps and complex NTS is also achieved by using safety monitoring, which composition depends on hydrogeological and engineering-geological conditions.An automated stability control system is considered that provides water pressure measurement in a structure, comparing it with reasonable critical values and transmitting information to the base computer of the open-pit managerin the form of water head values and danger signals.

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EXPERIENCE OF DESIGN AND TRANSITION FROM OPEN TO UNDERGROUND OREFIELD MINING

In the practice of combined mining of ore fields, the most common scheme is to conduct open-pit and underground mining, with a transition zone between these mining operations. The transition zone is defined as a dividing pillar, and

the reserves left in the transition zone are involved in mining for the period of completion of underground mining.

For example, during the joint mining of Zhezkazgan field by open and underground methods, mining operations were carried out with the separation pillar with a capacity of up to 100 meters. With the completion of open-pit mining, the reserves of the separation pillar were involved in the mining of underground mining, while the capacity of the separation pillar was grounded 30m at the end of mining.

The development of Nurkazgan deposit, represented by a stock work occurrence, was designed in a combined way - with the transition from open pit mining to underground mining without leaving the separation pillar. At the same time, simultaneously with the conduct of open-pit mining, the open-pit mining of underground reserves was carried out. Stocks of the lower ledge of the pit, 15–20m high, were drilled and blown up using quarry equipment, and the production of broken ore was carried out from underground mine workings. This scheme allowed making the transition to the underground method of working out the system for developing a subsurface collapse.

Previously adopted design decision, Ushkatyn-III field was developed by the open method. By 2006, there was a trend of lagging of mining operations on overburden on the northern flank of the deposit, where ore deposits with a length of 800-1000m were represented by close and low-thickness ore bodies. On the basis of new design solutions, a transition was made to the open-underground method of working out with the advance of open-pit mining at the depth on the southern side and the adit diagram for opening the reserves of the northern side by underground mining. This made it possible to reduce the volume of stripping work for a quarry by more than 100 million m^3.

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MODERN GEODYNAMIC MOVEMENTS IN THE NORMATIVE BASE FOR THE CONSTRUCTION OBJECT DESIGN*

The need is especially relevance for need for research modern geodynamic movements in the normative base of design for dangerous, technically complex, unique buildings and structures. Among such objects are hazardous production facilities (HPF) as required by Urban Planning Code of the Russian Federation. All mining companies belong to the HPF [1]. Building regulations 91.13330.2012 Underground mining governing the mine design do not apply to the design underground mine workings, passable in areas of high tectonic stresses at a value of horizontal stresses in the rock mass more γH. [2]. Most of

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the deposits are developed in complex geological conditions and do not meet the above conditions regardless of mining method. Neglect of modern geodynamic movements leads to disastrous consequences [3]. Accounting of geodynamic factors should be fixed at the legislative level, especially for important objects [4]. At the moment, it is necessary to finalize the existing normative base for the construction object design as well as mining companies using combined terotechnology taking into account modern geodynamic movements.

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ENSURING SAFE CONDITIONS TO RESUME MINING OPERATIONS AT THE MIR MINE ON THE BASIS OF COMBINED GEOTHECHNOLOGIES

The mine operation return is possible only by means of introduction the synthesis of combined geothechnologies, including reconstruction of the mine to create safe operating conditions of the underground complex and the subsequent development of the pit reserves in the transitional zone.

As an option of drainage method for the Mir pipe, we offer a surface permanent operating open pit water draining system to be constructed at level - 130 m. To implement this project a complete rebuilding of the Mir open pit will be required to reach the level of – 130 m with building a site no less than 60 m wide and construction of a complex of dewatering facilities and an open-pit drainage station on it. This facility should ensure collection and drainage of the overall volume of water entering the worked-out area of the pit.

The upcoming reconstruction of the open pit will be fulfilled under conditions of partly flooded pit with almost no accessible safety benches, and the upper contour of the open pit will be expanded to 60 m closer to the urban area that will require use of adequate methods of drilling-and-blasting disintegration of rock mass.

In the paper we have considered pit walls and berms stability of the mine to be reconstructed for subsequent final development of pit reserves in the transitional zone and estimation of daylight surface displacement.

It has been found, that the increment of earthmoving in the course of the wall cutback on the daylight surface was up to 10 cm in the interval of 100 m. The earthmoving activities are directed outwards of the pit of the mine and are tensile, therefore the limiting deformation values at the distance of 250 m from the upper edge of the pit generally satisfy to integral criteria of safe conditions: $\varepsilon = 2 \cdot 10^{-3}$. The zone of the mining operations impact on the deformation of earth's surface is located at a distance of 525 m from the upper edge of the open pit.

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DIAMONDIFEROUS DEPOSIT RESERVES DEVELOPMENT IN YAKUTIA USING HYDRAULIC MINING BY BOREHOLES

Expanding the resource base and increasing the volume of diamond production is a very priority task in the development strategy of ALROSA, a decision that requires revising the existing technological approaches to developing diamond deposits, both already on the company's mining sector balance and promising for future development. Steps in this direction are already being taken, in the near future the company aims to test the method of borehole hydraulic mining (BHM) of diamond-containing sands of buried placers that are unprofitable for exploitation by open and underground methods. This article discusses the most appropriate options for the technological schemes of downhole hydraulic mining during the development of alluvial diamond deposits in Yakutia, using the example of Nyurbinskaya alluvial placer located in Nakynsky ore field. The paper presents solutions for the organization of the production cycle in pilot development of a separate section of the reservoir, the structural and technological parameters of the BHM at the first stage of testing. A concept for the refinement of the remaining reserves of the flooded areas of the kimberlitic tube "Mir" based on the BHM method is proposed.

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ADVANCE OF COMBINED GEOTECHNOLOGY FOR THE DEVELOPMENT AND MINING OF DEEP LEVELS OF THE ARKHANGLSKAYA PIPE OF LOMONOSOV DIAMOND DEPOSIT

Geotechnological conditions of the deposit are very complex. This is due to the relatively low strength properties of the overlying and host rocks of the deposit within the design limits and high water abundance in the rock mass, which in entirety restricts the incline angle of the slopes of the designed open pit and requires construction and operation of capital-intensive and costly water-protection structures. These factors significantly reduce the efficiency of deposit development and narrow the boundaries of open-pit mining. Ineffective geotechnology results in a situation when ongoing open-pit mining is no longer possible, and the construction of an underground mine is not feasible. In these circumstances, less than 50% of the existing geological resource of the northern deposits is extracted.

The paper considers the combined geotechnology adapted for the geotechnological conditions of Lomonosov field of diamond deposits based on a combined mining plan, with the geometry of the pit profile changing with depth. It is known that greater stability is characteristic of the deeper zones of the rock mass constituting the pit wall, allowing increasing of the technically achievable slope angle [1].

The combined method of development allows avoiding construction of haulage ramps in the lower part of the open pit, which in turn allows increasing of slope angle from 46° to 65°. The construction of the lower levels of the pit in the host rocks with better strength characteristics provides a stable pit wall with steeper slope. Combined method of deposit development and slope construction without haulage ramps in the lower part of the pit enables 20° increase of the slope at these levels of the pit, and allows 3.5 times reducing of waste rock removal operations as compared to conventional pit wall design[2].

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JUSTIFICATION OF TECHNOLOGY OF HIGH OVERBURDEN BENCH STRIPPING IN COMBINED DEVELOPMENT OF ORE DEPOSITS*

The development of existing open cast mines is characterized by the complication of the mining and technical situation, associated with the transitioning of mining operations to deep horizons, an increasing overburden ratios, limiting working space and high loss of mineral resources beyond the marginal contour of the quarry. One of the ways to improve the efficiency of open geotechnology and the completeness of field development is to use technology with high overburden bench stripping, with a justification of the moment of an effective transition to the underground method of extracting reserves beyond the marginal contour of the pit.

Studies carried out earlier at ICEMR RAS have shown the possibility of increasing the effective depth of open cast mining of coal by an average of 18-23%, while, respectively, the volume of coal mined in the cut contour increases in a more economical way and the overall life of the deposit.

Changing the parameters of the working area of the quarry during the transition to technology with high overburden bench stripping requires the improvement of the scientific and methodological approach to the choice of parameters of open pit mining. The essence of the previously proposed method of determining the depth of the cut is that at the moment of maximum development of mining operations, which is characterized by the achievement of equality of the current and boundary coefficients of stripping, they start transition to high overburden bench stripping. This allows to reach additional mining horizons and expand the quarry at the top, while not exceeding the value of the boundary overburden coefficient. For example, for the open-pit mine Kaltansky Kuzbassrazugugol, a pre-project study of the technology for using high overburden bench stripping proved the prospect of increasing the

* The studies have been performed within the framework of the ICEMR RAS Research Project 0138-2014-0001

total coal production in the cut contours by 18% while maintaining an acceptable level of enterprise profitability.

Solving the problem of optimizing the period of transition to technology with high overburden bench stripping and then to underground mining of ore, together with substantiating the optimal parameters of the mine's logistic system for the combined mining of an ore deposit, differs significantly from the task of establishing rational parameters of coal mining systems. In addition, it obviously represents the actual topic of study.

At the same time, the fact that the transition to high overburden bench stripping is in itself contribute to improving the quality of blasting the ore mass, increasing the production capacity of the quarry due to the simultaneous explosive preparation of the high ledge, at a height twice the height of the basic ledges. The technology with high benches is characterized by wider possibilities of controlling the size of working sites and transport communications in the pit contour.

In addition, the transition to a combined scheme of ore mass transportation by open and underground mines and optimization of the area and application parameters of open, open-underground and underground geotechnologies will contribute to a significant reduction in operating costs and increase the efficiency and completeness of integrated development and mining safety.

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COMBINED GEOTECHNOLOGY OF UNDERGROUND EXPLOITATION OF LOW-GRADE MULTI-COMPONENT ORE RESERVES*

The most promising technology of poor mineral resources exploitation is internal particle-by-particle ore sorting [1; 2]. Widely tested for the conditions of processing off-balance ores at the surface with open-pit mining (Gaysky and Uchalinsky GOKs) [3; 4], this technology did not spread in underground mines using stoping methods with cemented backfill.

The need for a narrow grade classification by fraction requires the creation of a complex system of bunkers, several stages of crushing and screening. For existing conditions of underground mining, currently operated sorting complexes have low productivity and in fact require hoisting to the surface both the separation concentrate and most of the waste. To solve this problem, a combined geotechnology of the underground development of poor

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multicomponent ores has been proposed. It assumes a combination of underground high-speed conveyor belt stations of sensor-based particle-by-particle sorting separation with underground mobile backfilling complexes of modular type. Such complexes, which allow to produce cement backfilling mixtures in underground conditions, are a key element to the effectiveness of the disposal of underground separation wastes without their lifting to the surface.

The problem of determining the conditions and patterns of the joint exploitation of these two technologies has not yet been solved. A key feature of the joint operation of these geotechnologies is that separation waste is the raw material for the production of backfill mixtures in underground mobile backfill complexes. Thus, the ability to produce backfill mixes directly depends on the intensity and time of occurrence of separation wastes, their composition and storage conditions, transport, storage, as well as the needs of the complexes themselves for raw materials. Considering also that mobile backfilling systems constantly follow the front of backfill operations, the most optimal method for simulating such system is agent-based simulation, it allows describing the behavior of all system elements — stowing complexes, separation stations, LHD, dump trucks, etc. at the individual level, and their general interaction allows us to simulate the work of the entire system as a whole. Given that mobile backfilling complexes and underground particle-by-particle sorting separation complexes are still not widely spread in the mines, it is not possible to use the existing specialized mining design systems that simulate the operation of the mine.

To solve these problems, software that allows the creation of agent simulation models that characterize the new technological structure of the mining industry was adopted. Anylogic allows you to simulate the work of objects of the mining system of any complexity based on the Java programming language. This made it possible to evaluate the features of the interaction of underground complexes, as well as the mineral and raw material flows that are formed during their operation.

The created simulation model made it possible to estimate the dynamics of the flows: extraction conditions and ways of moving the ore mass to the sorting station; the volumes of the formed preconcentrate lifting to the surface; principles of organization of underground disposal of separation wastes; the need for cement and rock filler delivered from the surface to the underground backfilling complexes.

The model allowed us to estimate the production capacity on a different time scale. Analysis of the dynamics of production capacity by the ore mass of such mining system made it possible to determine its cyclic nature. It is established that the oscillations in production capacity are associated with the features of the involvement of dump trucks and loading-hauling-dump machines in the delivery processes of the rock filler and cement to the underground backfilling complexes. The model allowed us to estimate the amplitude and frequency of such oscillations. Also, the maximum and

minimum volumes of separation waste disposed underground, which is an important criterion for evaluating the performance of the mining-technical system, were determined depending on the initial parameters. The combination of underground mobile backfilling complexes of the modular type with underground stations for particle-by-particle sorting separation stations allows to exploit of poor multicomponent ores reserves.

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TECHNOLOGICAL SCHEMES DEVELOPMENT OF TAILINGS RUNOFF BOTH FOR FURTHER STORAGE AND FOR STOWING OPERATIONS

At the moment, most of the tailings are in a limiting position in connection with which there is a need to search for sites for the disposal of waste from mining enterprises. In addition, the issue of the consistency of the stored product is also quite important, especially in those cases when the quarry is used as a tank with an underground mine working under it. In this case, the storage of the current tailings is not applicable, since this may cause a man-made accident as a result of the breakthrough of the pulp into the underground workings. Based on what, the given three options are possible for different aggregate state of disposal of recycling:

1. Pasty.
2. Dry.
3. Monolithic.

At the same time, part of the tailing product can be used as an inert aggregate (according to this scheme, Gay underground mine is currently operating), on the basis of which it is necessary to take into account that in order to carry out the backfilling, it is necessary to dewater the pulp to the required moisture content (approximately 60 - 65% solids).

Dehydration can be carried out both by hydro-cloning and on high-density thickeners. At the same time after hydro cyclones overflows also need to be dehydrated. Thus, we obtain the following technological schemes, the concentration of tailings while this product is used for the preparation of the filling mixture, and stored in landfills.

This flow chart provides for two modes of operation. In the first case, after the pulper divider, part of the product is distributed to the slam-shut valve, and some to the tailings storage facility, and it is necessary to understand whether the slam-shut valve can take the entire volume of the tail product. During the second mode of operation, when the backfilling work will not be carried out, the entire volume of the condensed product will be fed to the tailings dump.

The concentration of waste tailings at the same time this product is used to prepare the filling mixture, and for storing it at landfills, it is dehydrated to a state of cake.

In the second variant, a dry scan of the tailings is provided for and in comparison with the first scheme; a workshop for the dehydration of the condensed product is added. Just as in the first version, this scheme provides for two modes of operation when conducting backfilling and when backfilling is not being conducted.

Hydro cycloning of tailings, after which the sand product is used to conduct filling operations, and the drain is concentrated and in a condensed state stored at closures.

The third option provides for backfilling operations on the hydro-cyclone sands, in this case the sand product will go to the slam-shut valve during the first mode of operation, the second will go to the closure, and the option of co-transport of condensed and sandy products is possible; Under this option, one of the main questions is which fractional composition is necessary for the backfilling work and whether it will be enough.

Hydro cycloning of the tailings of enrichment, after which the sand product is used to carry out filling operations, and the drainage is concentrated and then dehydrated to a state of cake.

The fourth option involves the use of hydro cyclone sands for storage operations and storage at a dry cake site. In this case, in the second mode of operation, a pitch product must be supplied to the dewatering.

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MINE PRODUCTION CAPACITY EXPANSION BY DRAWING MAN-MADE TECHNOLOGY-RELATED MINERAL DEPOSITS INTO DEVELOPMENT*

One of the most promising areas of mine production capacity expansion, with the increase of its saleable product output, is the drawing of technology-related mineral deposits formed in the earlier years into economic circulation [1,2]. In this context an extreme need emerges for licensing and entering of such assets on the state balance sheets. In compliance with the Mineral Law the recording of the reserves of technology-related deposits can be effected only upon the submission of mineral deposit developer's reports on the reserves evaluation and exploration, as well as findings and conclusions of the State Mineral Reserves Committee.

Presently, one of such assets is located in the Chelyabinsk Oblast, in the town of Plast; it has been formed by the accumulated waste materials from the processing facilities of the Novotroitsk gold-arsenic ore deposit. The results of the research into the achieved data in Rosgeolfond have shown that Novotroitsk gold vein deposit is unique in terms of arsenic concentrations and characterized by the essential gold content. The deposit is formed by quartz-arsenic-pyrite-scorodite veins and impregnations zones with high As, Pb and Zn content. Today, the deposit is registered in the reserves as inactive, with outbalance (non-commercial) gold reserves estimated at 3,670 kg, and those of arsenic estimated at 43,420 t.

The losses of valuable components in flotation tailings are estimated at 14-17% As and Au. In terms of absolute values flotation tailings contain 0.7-0.9% of arsenic and over 1.5 g of gold per tonne. Depending of any particular site of the deposit the ROM ore supplied to the processing plant at different times contained Ga (up to 12 g/t), Ge and Ag, which were not taken into account in the calculation of performance and economics of the Novotroitsk processing plant. In view of the prospects of the comprehensive development of the technology-related mineral formation at the Novotroisk deposit it is important to identify the associated valuable components in the tailings.

Geological evaluation performed in 2018 at the tailings storage facility shows that Au concentrations vary down the depth from 0.2 to 1.42 g/t Au, 0.2 to 4.6 g/t Ag and 0.07 to 0.56% As. Besides, the distribution of Au and Ag down the depth shows that the highest concentration of noble metals belongs to the horizon of 8-12 m, i.e., it is closer to the tailing pond bottom. The obtained results of chemical analyses for As and S correlate with Au and Ag

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concentrations that also prove the presence of noble metals in sulphide minerals, mainly in arsenic pyrite.

Within the framework of optical-mineralogical studies the material of the tailing pond was classified by size (-d max+2.5 mm; -2.5+1 mm; -1+0.25 mm; -0.25+0.1 mm; -0.1+0.071 mm; -0.071+0.04 mm; -0.04+0 mm), according to that, 20 samples were made based on epoxy resin. According to the classification of medium- and fine-size rocks the mature tailings of ore from the Novotroitsk deposit belong to clayey silts, as by results of particle size distribution the mineral processing wastes are mainly of silt rock size (-0.1+0.01 mm).

Mineral composition, size, shape of grains, as well as nature of ore and rock-forming minerals intergrowth have been studied by light-microscopy method.

Tailings contain small amounts (up to 2-3%) of ore minerals: pyrite, arsenic pyrite, traces of pyrrhotine and chalcopyrite, both as released grains, and intergrowth with other minerals. The average size of mineral aggregates is 0.03x0.05 mm. Non-metallic materials are mainly quartz and mica (up to 96%). The pattern of ore and rock-forming mineral intergrowth boundaries is irregular and serpentine.

Some regularities of the distribution of tailings moisture and pH medium in and at the bottom of this man-made, technology-related asset were discovered. Presently, the mature tailings of the Novotroitsk deposit are neutral, closer to weakly alkaline medium. The natural moisture of ore processing tailings of the first 4 m is characterized by maximum allowable indices for mechanized mining, with the machinery operation directly on the tailing pond bottom, and it does not exceed 15%. The horizons of waterlogged and water-flooded rock occur at the lower hypsometric depth.

The analysis of the studies performed at the stage of geological evaluation of the processing wastes of ore from the Novotroitsk deposit, and studying of the available archived documentation of the Rosgeolfond suggest the conclusion on the worthiness of this technology-related asset for commercial mining and reserves recording. With this purpose it would be necessary to perform detailed geological exploration of the tailing storage facility and to register the reserves in the State Balance Sheets.

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RATIONALE FOR A GEOENGINEERING SYSTEM STRUCTURE IN VIEW OF IN-MINE ELECTRICITY GENERATION ON THE BASIS OF PROCESS SLURRIES*

The growth of electricity consumption by a mine in the process of turning to a new wave of technological innovation with the intensification of mining processes and broad-scale application of automation, robotization and electrification, alongside with ore reserves quality degradation and ever growing mineral deposit mining depth, indicates the necessity of search for additional energy sources. In industrially developed countries of the world, additional renewable sources of electrical power are used on an increasing scale for the improvement of energy efficiency of mining processes [1].

As a result of theoretical research and field studies at sites the IPKON RAS researchers have identified the conditions and criteria of the application of free energy of the technological process flows. It has been found that water drainage flows freely going via interhorizon boreholes possess a great energy potential; therefore, recuperation of their energy and its use as an additional source of electrical power in conditions of an ore mine is an extremely important task [2, 3].

In-mine tests with tailor-made low-capacity hydraulic turbines (HEP) have shown that the existing ore mine water by-pass systems do not meet the requirements of hydraulic flow energy recuperation. Long horizontal sections, numerous changes of flow directions and the absence of a system of the rationale of design parameters of water drainage bypass boreholes with due account for opportunities of the collection and recuperation of energy generated by moving masses have determined the necessity of the elaboration

* The studies have been performed within the framework of the ICEMR RAS Research Project 0138-2014-0001

of recommendations on the design of a mine water drainage bypass system, including the following:

- justification of the sufficiency, and area and height at HEP for water drainage flow movement;
- creation of groups of overflow boreholes of a herringbone pattern with linked mouths;
- providing of the minimal volume of slurry required for stable regeneration of energy by way of the regulation of the quantity of simultaneously operated bypass boreholes
- rationale for the necessity and parameters of horizontal sections of the system of pipelines and underground workings;
- estimation of the parameters of additional chambers and other workings in the rock mass allowing the installation of hydroturbine plants in the areas of water flow discharge, and providing the access for maintenance and service;
- elimination of drastic variation of flow directions in a water drainage system (over 45^{o}) and elevation difference on the way of a hydraulic flow movement;
- providing of the hydraulic flow free departure from the operating unit of a hydroturbine plant.

Opportunity of in-mine electricity generation based on the process hydraulic mixture application determines the necessity of the rationale for design parameters and structure of mining engineering systems based on the philosophy of in-situ recovery of additional renewable energy sources.

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MECHANIZM OF EXPLOSION WAVE PROPAGATION IN UNDERGROUND MINE CONDITIONS IN PYRITE DEPOSIT DEVELOPMENT*

Multicomponent pyrite (sulphide) ore is the main raw material for non-ferrous metal production. Nearly 75% of the total world copper production

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come from the processing of pyrite ore [1]. Pyrite ores are classified as sulphur-pyrite, copper-pyrite and complex pyrite ores. In ore of copper-pyrite deposits such copper minerals as chalcopyrite, bornite, chalcosine occur; besides, there prevail such iron sulphides as pyrite, pyrrhotine, marcasite. Such minerals as zinc, lead and barite occur in ore of complex pyrite deposits. It is notable that the development of these deposits involves extra difficulties, as pyrite ore is highly liable to oxidation, particularly in case of its fragmented aerosol state, and in certain conditions [2] it can cause and more than once caused sulphide dust explosions in mine workings.

Based on the earlier results of the studies [3] the assessment has been made of mining processes risks concerning the formation of sulphide aerosol explosive concentrations in the mine air. In this connection it has been found that the greatest hazard is associated with drilling and blasting of sulphide rock mass, as in this case dust formation intensity is the highest. In the course of drilling and blasting processes a cloud of the explosive concentrations of sulphide dust is formed, and it is a necessary condition of the initiation and propagation of the flame front.

Mechanism of sulphide dust explosion initiation is associated with the propagation in local sources, which serve as a conductor of the blazing fire front, or combustion products moving to the zone, where critical concentrations of sulphide dust are accumulated in the mine air or on the walls of an underground working; and this critical concentration can lead to immediate propagation of the sulphide dust explosion. The flame front propagates together with gaseous products of explosion to the nearest layer of sulphide dust heated to a high temperature.

Thus the ignition of the nearest layer of sulphide dust occurs due to explosion gaseous products heated to a high temperature. Subsequently, the explosive pulse is transmitted from burning particles to the adjacent layer of non-burning particles, and then to another such layer. Thus, the mechanism of ignition is as follows [4-6]: thermal energy emitted by the flame front is spent for the heating of the adjacent layer of cooler dust particles, as well walls of an underground working and enclosing gas volume. In this case, the course of chemical reactions is intensified, and the temperature rise is adiabatic in nature, and rises to the combustion temperature, followed by the rapid oxidation of sulfides, with the release of a significant amount of heat, which allows you to maintain the process temperature at the required level. The oxidation process abruptly changes from the kinetic to the diffusion regime, with the transition moment being characterized by the sulphide ignition temperature.

The performed analysis has shown that the necessary and sufficient conditions of sulphide dust ignition in the mine air are as follows:

- amount and density of sulphide dust distribution in a mine working is sufficient for dust particles contact required for heat exchange;
- presence of local sources - conductors for the propagation of flame front and thermal processes, such as naked cables, wires, metal roof support, and equipment resulting in the expansion of the ignition zone, while the presence of insulation materials or elements, such as water, non-flammable fluids, and barriers minimize such zones;
- temperature of an ignition source is nearly critical;

- thermal capacity of a combustion source is sufficient for ignition;
- emitted heat in a combustion zone is greater than heat losses.

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OUTLOOK OF EXPRESS COMPOSITION CORRECTION USAGE FOR FILLING MIXTURE ON FINE SAND

The use of thin (modulus of particle size 0.7-1) and extremely thin (modulus of particle size <0.7) sand in the production of backfilling works gives the following advantages: low stratification during transportation, minimal abrasive impact on transport pipelines. This is due to the presence of a large number of small particles in the sands, which provide a high water retention capacity, which positively affects the rheological properties of backfill mixtures. At the same time, the high water demand of such sands leads to an increased consumption of cement.

Often, the water demand of fine sands is not constant and can vary considerably over different production horizons. Such changes in water demand lead to a change in the rheological properties of filling mixtures. There is a need for continuous monitoring of the water demand of the sand entering the technology and the adjustment of the compositions to ensure the required grade strength while maintaining the required rheological properties of the mixtures.

For rapid adjustment of filling mixes under production conditions, a rapid method is proposed based on the sand water demand, which is estimated using Suttard instrument.

Based on the available data on laboratory studies, a nomogram for determining the amount of water and cement consumption per 1 m3 of mixture to obtain grade 40 at the age of 90 days (see figure) was constructed for the condition for determining the sand water demand for spreading using the Suttard device.

To calculate the flow of water and cement, you must perform the following steps:

1. On the Suttard device, determine the water requirement (%) of sand for a spread of 230 mm. When using sand with natural moisture - recalculate water demand for dry sand.

2. On the nomogram to build a vertical line corresponding to the received water demand.

3. At the points of intersection of the vertical with the flow lines of water and cement to take readings on the costs. Water consumption is calculated by the line of the corresponding natural humidity of the sand.

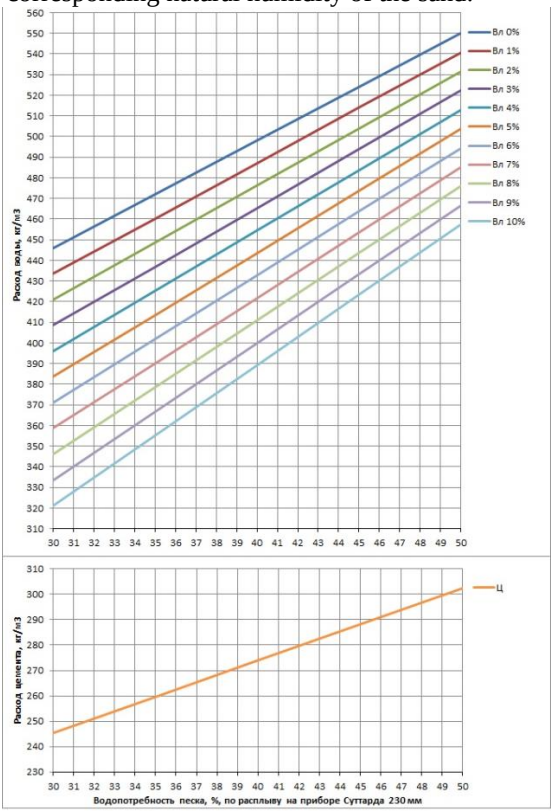

Figure - Nomogram for adjusting the flow of water and cement depending on the water demand of sand

For the production use of such nomogram it is necessary to build them on the basis of data directly from the technological process for the preparation of backfill mixtures.

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MINE PLANNING DESIGN CRITERIA FOR AUTONOMOUS TRUCK OPTION

The autonomous haulage system allows to haulage materials inside a mine site from one point to another without the need of a truck driver. In very simple words, AHS is a hardware-software system, which allows a truck to move along a defined haul road without the need of an operator.

Due to the potential productivity, safety and cost advantages, many mining companies have decided to implement AHS in their operations.

The process of mining planning shall necessarily take into consideration, among other variables, the type of equipment to be used in the mining operation, and accordingly develop the mining design, with the purpose of optimizing performance. Therefore, AHS requires some special considerations with the purpose of minimizing interferences produced in traditional mining operation and particularly in AHS implementation.

One of the potential advantages of AHS, which makes it attractive to the mining industry, would allow to achieve a more effective use (effective hours) in comparison with traditional trucks, because shift change or meal time is removed or reduced. However, this longer effective time shall necessarily be accompanied with haulage cycle time optimization.

To optimize haulage cycle time, an alternative is to increase the average speed of a truck in the haul road, minimizing the interference produced in the route.

The planning process shall necessarily consider these interferences at the moment of developing the haul routes, and shall reduce them to the minimum.

The above-mentioned interferences may be:

- Road crossings
- Switch back
- Narrow haul roads
- Coexistence and/or crossings with other mining equipment
- Obstacles and others

Criteria to be considered at the moment of designing an open pit with autonomous trucks are set out based on the experience in autonomous haulage system implementation and mining design assessments for traditional and AHS sites.

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IMPROVING RISK ASSESSMENT REGULATORY WHEN DEVELOPING OREFIELDS

Analysis of the regulatory framework has shown that, at the present time when developing ore fields, risk assessment is regulated by the following documents:

- Federal Law No. 116 "On Industrial Safety" (Federal zones of July 21, 1997);
- Safety Guide “Methodological framework for conducting hazard analysis and risk assessment of accidents at hazardous industrial facilities” (Order of Rostechnadzor No. 144 dated 04.04.2016);
- International Standard ISO 31000 2-edition 2018-02 Risk management - guidance.

The analysis of the terminology used in regulatory documents in determining the risk, objectives, methods for assessing and managing it showed the absence of a comprehensive and unified methodological approach. In this case, the first two documents regulate the assessment of the risk of accidents through the development of such documents as the industrial safety declaration and safety justification, and the latter defines general approaches to risk assessment, including for obtaining an SRO certificate of approval. From the analysis of the developed documents, it follows that at the design stage, the selection of the main technological solutions, the risk assessment is not performed.

The data of annual Rostekhnadzor reports on injuries and accidents in the mining industry indicates that the largest number of them are associated with technological processes - with collapse, work in transport and with mechanisms. Whereas such traumatic factors as electric shock, poisoning, and others, quantitative risk assessment techniques are present in the regulatory documents, accounting for no more than 10% of the total number of accidents. The above indicates the need to develop methodologies for assessing the technological risk associated with man-made damaging factors.

The analysis data of the top 10 risks according to KPMG for the period 2015-2018 conducted by interviewing specialists of mining companies shows the greater importance for them of market, social, environmental risks, risks of government regulation, and the risk of safety and labour protection is in last place or not at all in the top ten. It is obvious that market and (or) price risk management can be carried out only by changing the parameters of technological processes up to the transition to new, less expensive technologies, which will lead to an increase in techno genic traumatic factors.

The current situation of the lack of techniques, taking into account the specific features of the industry, geographic location, mining and geological conditions for the development of reserves and the formation of industrial

wastes, indicates the need to develop an industry standard for risk assessment that considers the processes of mining at all stages of the enterprise's life cycle to its liquidation.

Taking into account the trends of integrating the development of the mining industry into other industries in terms of using technologies or processes that were not previously characteristic of the industry, for example, fracturing technologies, hydrometallurgy processes, etc., it is necessary to further develop safety guidelines for specific technologies.

Creating such a hierarchical regulatory framework, in our opinion, will contribute to the development of the mining industry through the use of advanced technologies, taking into account the "understanding" of risks and increasing the efficiency of its activities in general.

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LIFE CYCLE ASSESSMENT OF MINING AND PROCESSING PRODUCTION

The importance of the problem of environmental protection and possible impacts related with manufactured and consumed products increases interest in the development of methods aimed at reducing these impacts. One of the methods developed for this purpose is life cycle assessment (LCA).

Research objective: assessment of the impact of mining and processing on the environment applying the life cycle assessment method.

Mining production is a significant source of disruption and pollution of all elements of the biosphere. During the extraction and processing of minerals, large amounts of enrichment wastes are generated, the storage of which requires significant areas for their placement, which in turn leads to a change in in terrain, a violation of engineering-geological, hydrogeological and ecological-geological conditions of the waste storage area.

In this regard, the assessment and forecast of the extent of their impact on the environment is very relevant and necessary task, since it allows developing of effective environmental protection measures in order to prevent environmental damage.

One of the most effective methods for assessing the impact of forecasting on the environment is life cycle assessment, since this method allows us to consider not only the stages of production of products, but also the stages of natural resources extraction, manufacture, transportation, operation and disposal, i.e. "from cradle to grave". In the field of waste management, applying of LCA methodology plays an increasingly important role in choosing the most successful waste management solutions. In the case of LCA,

the waste management system is a taken as the basis for comparing the environmental performance of different waste management options and for strategic decision-making.

The assessment is carried out in order to obtain a comprehensive analysis of the environmental impact, which provides more reliable information for making economic, technical and social decisions. It should be emphasized that LCA itself does not solve environmental problems, but rather provides the necessary information to solve them.

Thus, the LCA method is increasingly being applied in various industries. In addition to direct application for product life cycle assessment, LCA is also used in a wider context for developing complex business strategies and public policies relating to different aspects of society.

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ADAPTING THE WORLD'S PRACTICE OF RISK ASSESSMENT IN CAVING SYSTEMS FOR UNDERGROUND MINING AT YAKUTIA KIMBERLITE DEPOSITES

High-performance development caving systems are characterized as high efficiency, while subject to high risks associated with mountain and air strikes, uncontrolled water breakthroughs (sludge), the consequences of which are caused by serious accidents leading to death and loss of large quantities of reserves. At the present time, in connection with the transition to the underground method of mining low-value ores, the practical interest of mining companies in caving systems, including during mining of Yakutia's kimberlite pipes, is increasing. The main deterrent to their widespread use in our country is the lack of domestic practical experience and risk management.

The analysis of world experience of caving systems at mines in Australia, South Africa, Canada, etc., revealed the main technological risks and the main methods of managing them at the current level of development of caving technologies. Existing methodological approaches to risk assessment, such as the Australian state standard for the mining industry, a special risk assessment methodology when using caving systems CaveRisk, etc., define the principles of identification, assessment and risk management methods depending on the stage of the project life cycle and as a result of changing knowledge about the mining and geological conditions of its implementation. The risk level of a project, the accuracy of which is determined by the effectiveness of its management, is established in most cases on the basis of assessments of external and internal experts based on their experience, ideas about the reliability of the initial information and the correctness of calculations of the main process parameters.

The lack of domestic experience, the uniqueness of mining and geological conditions and proven risk assessment methodologies determine the relevance of adapting existing risk assessment methodologies not only for making decisions about the development of Yakutia's kimberlite pipes by caving systems, but also their effective implementation at all stages of the life cycle.

An assessment of the main risk factors in the implementation of caving technologies has been carried out and the main provisions of the risk assessment methodology have been developed taking into account the conditions for developing the kimberlite deposits of Yakutia.

The risk assessment of the caving technology implementation is based on dynamic risk criteria integrated into technological processes, taking into account the mining and geological, mining and technical conditions for the development of kimberlite deposits.

The proposed risk assessment methodology will allow substantiating the main technological parameters and timely adjusting them at all stages of caving technology implementation depending on changing factors of the external and internal environment.

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THE CONCEPT AND THE PRINCIPLES OF STEADY FUNCTIONING AND DEVELOPMENT OF MINING AND TECHNICAL SYSTEMS DURING TRANSITION PERIODS

Mining and technical system (MTS) on the one hand is an element of larger systems (for example, the mine operations (MO) which have an impact on stability of its functioning, with another – itself influences the systems of lower level (for example, transport system, development system, etc.). Each of the listed systems is characterized by a certain structure and performs peculiar only to it functions. One of the main objectives uniting all systems is effective work with information (the analysis of an environment of commodity markets), financial (the cost of resources, etc.) and the material streams (the equipment, materials, etc.) arriving from the external environment on the MO and also the streams coming from the MO to the external environment (products in the set volume and the required quality, different assignments, technogenic objects and emissions in the environment, etc.).

In the conditions of the unstable external environment, upon transition from one development stage to another, subsystems of the MO have to submit to the purpose of ensuring steady functioning of the enterprise – to providing output streams with the set parameters. During this period stability of MTS changes that has an impact on a condition of economic, social subsystems of the MO, and also on the state of environment caused by changes in parameters of technology and engineering procedures. It demands development of the new approaches and the principles of management of work of the MO based on coordination of economic targets with the purposes in the field of ecology and social development.

Authors of the real work developed the concept and the principles of steady functioning and development of mining systems during the transition periods providing coordination of economic targets of subsystems of MTS with the purposes in area of social development of the mining enterprise and environmental protection. The idea of consecutive transformation of subsystems of MTS at all design stages and operation considering economic, social and ecological aspects for the purpose of ensuring the set parameters of functioning of the MO is the basis for the offered system of the principles.

GEOMECHANICAL JUSTIFICATION OF COMBINED GEOTECHNOLOGY PARAMETERS

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GEO MECHANICAL JUSTIFICATION OF DESIGN DECISIONS ON OPENING AND UNDERGROUND DEVELOPMENT OF ORE BODIES OF THE DEPOSIT PIONEER

While justifying the safest design solutions in the conditions of transition to the underground method of mining the Pioneer gold deposit, a set of studies was carried out, including geodynamic zoning of deposits at stage 1 with the definition of a complex of physical and mechanical properties and an assessment of the stress state of the rock mass. According to the results of the morphometric analysis of the relief, using the data of satellite geodesy and GPS observations, seismic materials, the modern stress field in the field massif was reconstructed, in which, as established, horizontal compressive stresses with an orientation on SW. predominate. To assess the stability of the rock mass, the following factors were calculated: rock quality indicator characterizing fracturing in the block - RQD, rock mass rating - RMR and geological rock strength index - GSI [1]. Based on the generalization of the obtained data, the mine field was zoned out according to the degree of stability into 3 groups (relatively stable rocks, medium resistance rocks and unstable rocks), to develop effective measures for the protection and maintenance of mine workings. At the final stage of the research, multivariant calculations of the stress-strain state by the finite element method were carried out, the results of which allowed us to establish safe parameters (power) of protective safety pillars formed during the mining of ore bodies ore reserves, as well as assess the stability of structural elements of the development systems, rational order and priority mining ore bodies [2]. When assessing the stability of the main elements of mining structures, the criteria of brittle and shear failure were applied [3].

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PHYSICAL SIMULATION OF OPEN PIT SIDES WITH BACK STEEP BEDDING

To date, a large number of different methods and calculation schemes have been developed for assessing the stability of open pit sides and ledges. However, especially with the reverse fall of the layers, non-standard cases of deformation of the near-side massif are observed, for example, in the form of bending and tilting steeply dipping layers with the formation of inverse steps.

In connection with the incompatibility of these fracture mechanisms with the classical models in the “Rules for ensuring the stability of slopes on coal cuts”, corrections are given to the formulas for calculating angles for an isotropic near-bed array. The use of such amendments due to the narrow range of conditions for which it is established has limited application and often requires clearance of open pit mines at very flat angles. In addition, the amendments take into account only the magnitude of the friction angles on the contacts, and the magnitude of the clutch is ignored. However, in many cases, for example, in a cryolithozone, the neglect of a clutch can have a significant effect on the stability of the pit walls.

Therefore, we carried out a physical simulation of the pit walls with steeply dipping stratification directed to the array. In the simulation, different contact conditions between the layers of rocks were considered. The simulation covered both the influence of friction angles and the adhesion values.

In the course of physical modeling, the dependences of the course of model deformation at each stage of its development were constructed. The resulting displacements were compared with the safety factors determined by the method of limiting equilibrium.

In the course of the simulation, it was found that with the strength properties of contacts approaching the strength of the main massif, the most likely destruction along a smooth curvilinear sliding surface, like a uniform slope, with less strong contacts, the most likely destruction mechanism combines the bending of the layers curvilinear surface, with even lower contact strength ("weak contact") - the bends of the layers, followed by tilting.

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GEOMECHANICAL PROCESSES DURING THE UNDERMINING OF TECHNOGENIC AND NATURAL ROCK MASSES

Undermining of technogenic and natural rock masses located in the areas of mining influence is accompanied by different geomechanical processes, such as sinkholes and surface cracks formation, landslides development on natural and man-made slopes, open-pit sides, etc. These processes adversely affect the safety of mining, infrastructure facilities and the environment. In particular, on the undermined earth's surface of the mine named after Ruban in Kuzbass ground failures formation has been detected due to longwall coal mining. In addition, in the new section of the mine field there is a hydraulic mine dump in the former open-pit. Its undermining can lead to the emergence of catastrophic inrush of water or effluent into underground excavations or on the territory beyond the external borders of the structure. The investigation of surface failures has been carried out and it was found that the main reason for their formation is subsidence and ground movement of rock masses and earth's surface as well as structural and mechanical features of rocks and soils. The typification of their forms has been developed according to the morphological features and the prediction method has been proposed based on empirical dependencies and numerical modeling using FEM [1, 3]. Analysis of the mining and geological conditions of the site of the hydraulic dump disposal, industrial experiments on the experimental longwall with the registration of surface and deep deformations of the massif, as well as changes in the hydrostatic pressure in the undermining massif, analytical calculations and numerical simulation have been implemented. This allowed to substantiate the safe mining depth of coal seams under the water body (hydraulic mine dump) [2] and to assess the stability of tailings dams [4], as well as to develop recommendations for ensuring the safety of underground mining and operation of the hydraulic mine dump during its undermining.

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STABILITY OF HIGHWALL SLOPES IN CREATION AND OPERATION OF TECHNO GENIC AREAS

The formation of techno genic areas on the basis of quarries for the purpose of their subsequent use for disposal of industrial wastes and products of their processing allows substantiating the most effective values of the resulting angles of high wall slopes. This is due to the possibility of using temporary stability at the stage of finalizing balance reserves with its subsequent restoration to normative values due to timely shipment of man-made capacity during operation. Based on the phase state of the disposed waste and the hydro geological characteristics of the deposit, the open pit's area used as a techno genic reservoir may be flooded and not flooded. The first case is typical for the disposal of fluid waste from the beneficiation industry, including the provision of dehydration of tailings. The second option is typical when storing waste products of metallurgical production and products of their processing into the open pit area.

For the conditions of a non-flooded quarry, maintaining the stability of the pit side is possible due to measures to strengthen the geomechanical design - separation of the upper part of the slope in order to unload the active pressure prism and load the lower part - to create a stop prism.

For the conditions of flooded developed space as the water level in the recess increases, on the one hand, the area of the submerged part of the landslide prism increases, and on the other hand, the hydrodynamic pressure decreases. When the excavation is flooded to the groundwater level, the hydrodynamic force will be zero, and the influence of water will be manifested only due to the decomposition of rocks forming a slope. As a result, it is possible to reduce the values of adhesion and the angle of internal friction. At the same time, the negative impact of soil decompression on the stability of the slope of a completely submerged excavation is usually insignificant, since due to the weighing effect, the weight of the landslide prism will also be reduced.

Restoration of the long-term safety factor of the quarry slope, taking into account the dynamics of the decrease in the strength characteristics of the adjacent rock mass as a result of the natural flooding of its developed area, is ensured by loading with the product of the current tailings treatment of the processing plant.

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BASIS FOR STABILITY METHODS OF BUND WALLS IN CREATION AND OPERATION OF TECHNO GEHIC AREAS AT DUMPS OF STRIPPING SOILS

The use of stripping soils for the formation of techno genic areas is one of the promising fields of sustainable development in the mining system. This is possible through the creation of a receiving tank in a limited area and through the formation of enclosing dams around its perimeter. At the same time, the slopes of the existing dump can be part of the created techno genic area, which can later be used to place industrial waste and their products in it. Regardless of the phase state of the stored waste within the created capacity, water accumulation is inevitable, which negatively affects the stability of the enclosing dams.

In this regard, the stability of enclosing dams should be considered in the likeness of the stability of rock dumps. The only difference from the standard calculation schemes is that the lower part of the blade to a height of 2 - 3 m from the foot will be flooded. The dumping of dams in the conditions of the Ural region is made from rocky sketches with rock strength in a piece of 30–80 MPa or more, that is, landslide deformations are possible only by squeezing out weak soils of the base, or by contacting the dump mass with the base [1]. Taking into account the fact that the base of the dams is mainly composed of brown loams solid and semi-solid, to a depth of from one to several tens of meters with interlayer of soft plastic loam, and also loam with rubble appears, less often rocky soils approach the surface of the earth, ensuring stability of enclosing the dam boils down to strengthening their foundations. The most effective way to ensure the strength characteristics of the base of the walls is to remove weak loose rocks by mining them.

In the case of a change in the height of the wall from 10 m to 78 m, with an average bulk density of rocks 1.8 t / m3, the maximum compressive stress at the lower brow will vary from 0.06 MPa, for a height of 10 m, and up to 0.48 MPa with a wall height of 78 m. Accordingly, the angle of internal friction will vary from 570 to 470.

Also, in order to assess the shear characteristics, you can use ADJ. 18 [1], according to which the shear characteristics of dump rocks, using the example of Olenegorsk field, are: C = 0.04 MPa, φ = 350.

In order to assess the stability of enclosing dams during the creation and operation of man-made spaces, use both options for the characteristics of the wall mass:

C = 0 MPa, φ = 470; and C = 0.04 MPa, φ = 350.

Calculation of sustainability should be carried out taking into account the three main scenarios of buckling [2]:

- the sliding surface is fully realized in the body of the slope, i.e. flat isotropic slope scheme (Va RRMI scheme);
- implementation of the landslide on the contact of the body of the blade with the base (scheme Vb and VIIIa RRMI);
- implementation of the landslide with the extrusion of weak soils of the base (scheme VII RRMI).

According to the results of calculations, it is necessary to choose the most dangerous sliding surface from all three scenarios.

For each of these scenarios, two stability calculations should be carried out:

1. Determine the maximum height of the slope (layer), poured at an angle of 380 (angle of repose).

2. Determine the maximum permissible angle of slope at its fixed height. Reducing the angle of repose compared with the angle of repose is achieved by leaving inter-tiered (interlayer) berms.

Thus, for the given conditions, from the point of view of stability, the bund walls can be filled to the full height at an angle of repose by one tier. The number of tiers and the width of the berms between them can be determined on the basis of technological requirements.

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IMPACT ASSESSMENT FOR DESIGN PARAMETERS OF FRICTION BOLT ON ITS SUPPORTING STRENGTH

Safety of work in the mine workings is ensured by timely and high-quality carrying out of the outcrop surface strengthening. Fastening is performed frame or anchor lining. Each method has its advantages and disadvantages.

In the last decade, the use of friction-type anchor bolts has increased at an especially fast pace: Swellex and Split Set (the Russian equivalent is self-fixing anchor bolts). Taking into account the degree of mechanization, execution time, cost and reliability, the priority is the use of self-fixing anchor bolts (SAB). The time for its installation does not exceed 2-3 minutes. Excluded performance of work takes place directly in the loose zone of production.

Despite the active use of supports of type SAB, the analysis of the effect of the basic parameters of the anchor on its bearing capacity is not presented in the open seal. This is due, primarily, to the lack of calculation methods that take into account the complex loading pattern of the anchor.

The operation of SAB is based on the creation of friction forces on the surface due to the elastic deformation of the walls of the rod. In this case, the key is to ensure the effective bending stresses σ less than the yield strength σt. The value of σ is determined by the structural parameters: the thickness of the wall of the rod, the difference in the diameters of the rod and the hole, the width of the open groove of the rod. The developed engineering technique makes it possible to perform an analysis of the dependence of stresses in a rod on structural parameters.

It was established that the dependence of σt on the wall thickness has the form of a cubic parabola, and on the difference of diameters - quadratic. In this regard, in order to ensure the condition $\sigma t < \sigma$, it is more effective to reduce the wall thickness of the anchor. The minimum allowable thickness is determined by the required load capacity of the rod, numerically equal to the value of the carrying capacity.

For typical drill hole diameters, the developed stresses in the anchor rod are determined with possible combinations of structural parameters. Based on them, a forecast of a single-length anchor bearing capacity was compiled. This allows the consumer to choose the SAB with reasonable parameters.

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MODELING MASSIF STATE FOR PARAMETERS CALCULATION OF TWO-LEVEL ROOF BOLTING OF MINE COUPLING AT MINE SITES

Introduction

In Karaganda coal basin mines in recent years, roof and rope bolting have been widely used. One of the urgent issues in the application of roof bolting is the optimal length of the roof [1]. The work is devoted to the substantiation of the optimal length of roof bolting of the interfaces of mine workings on the basis of a numerical model.

Methodology

A number of numerical experiments based on the application of the finite element method were performed to substantiate the optimal length and number of roof bolting of the interfaces of mine workings. Numerical experiments were implemented using RS3 software developed by Russcience. During the experiment, geo mechanical models of various conjugations were created (rectangular and acute-angled intersections, branches rectangular, acute-angled and radially, branching at an angle and along curves, triangular knot, rectangular, acute-angled and obtuse-angled abutments). The simulation results were systematized and the corresponding dependencies obtained.

Results

As a result of the studies performed, the dependences of the development of inelastic deformation zones on the depth of mining operations were obtained. In addition, the optimal parameters of roof bolting are determined depending on the depth of placement of the mates, on the strength of the roof rocks, on the coupling type of mine workings.

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THE CONTROL RESULTS OF THE UNDER QUARRY ORE CEILING MOVEMENTS DURING THE DEVELOPMENT OF THE UNDERLYING STRATA

Under the terms of mining safety, excavation of under quarry reserves is characterized by the greatest complexity regardless of the development system adopted [1]. Spent quarry is a potential source of accumulation of flood waters, sediments and debris from the sides, which requires special measures to control hydrogeomechanical processes [2.3].

The development of a kimberlitic tube at the Aikhal mine of SC ALROSA below the bottom of the quarry is carried out under the protection of the under quarry ceiling using a layered development system and hardening tab. For the timely adoption of measures to ensure the safe conditions of clean-up operations, mandatory monitoring of the displacement process parameters and deformation of the ore ceilings is provided [4]. An integrated approach to the organization of geo mechanical monitoring, based on the use of laboratory, numerical and natural methods of research [5], is proposed.

The analysis of the results of numerical calculations of the stress-strain state (VAT) of the under quarry massif made it possible to substantiate the monitored parameters, select methods and zones for controlling the deformation processes in the ceiling. Observations of the ceiling movement are carried out on the stations of the contour and depth reference points, profile lines and borehole visual observations.

In order to evaluate the results of monitoring, an experimental analytical method for determining the limiting fracture parameters was proposed, based on the results of visual observations of the destruction of the contour of the wells and the numerical assessment of the VAT [6].

According to the results of experimental observations, the adjustment of the parameters of the computational model was used, which was later used to predict changes in the VAT of the ceiling in the process of development of cleaning works.

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PERSPECTIVE SCENARIOS OF A GEOMECHANICAL SITUATION IN THE COURSE OF RESERVES' DEVELOPMENT USING CAVING MINING METHOD UNDER CONDITIONS OF THE UDACHNAYA PIPE DEPOSIT

The Udachnaya pipe has been developed using open pit mining method since 1967. Having reached the depth of 640 m the open pit operations were stopped in 2015 and the remaining part of the reserves is mined using underground mining method (the underground mine was commissioned in 2014).

In accordance with the project for development of reserves of the Udachnaya pipe using underground mining method a system of induced block caving with bottom ore draw is employed. Besides, an opportunity to use free caving mining method is being actively discussed nowadays.

At the same time currently non-operating open pit is used for partial interception and discharge of surface waters, as well as for exhaust of dirty air through audits entering the open pit.

The authors of this paper investigate a development of displacement and open pits walls deformation processes, evaluate a depth of mining operations, that would allow to launch a construction of underground water drainage complex of increased capacity and modify ventilation system and also define basic requirements for the system of geomechanical monitoring.

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PROCESS SIMULATING OF BLUSTING USING CHARGES WITH WATER CIRCULAR CLEARANCE

One of the ways to improve the quality of ore mass preparation in an explosive way is to use explosive charges with a water circular clearance, which is confirmed by the positive experience of its use in open-pit mines under conditions of mining kimberlite pipes of Yakutia. The use of a water clearance provides the so-called "gentle blasting", which leads, according to various estimates, to an increase in the yield of intact diamonds by 20%, a decrease in the specific consumption of explosives by 1.4 times and in general the cost of drilling and blasting by 20-30%.

Experimental industrial tests of kimberlite blasting with a water circular clearance in the conditions of the Aikhal underground mine showed the promise of this direction of blasting operations development on the kimberlite pipes of Yakutia. The constraining factors of large-scale implementation of this technology are the insufficient knowledge of the process of rock destruction in the presence of a water circular clearance, the lack of a methodology for substantiating the technological parameters of drilling and blasting, taking into account the specifics of the interaction of detonation products and the massif in the presence of water clearance.

In the process of research, a numerical simulation of the wave loading mechanism of rocks in the charging cavity was carried out during the process of explosion of the explosive charge in a single hole without a clearance, as well as in the presence of water and air circular clearance. The effect on the nature of the stress distribution in the rock mass as the wave attenuation of the charge structure, the size of the circular clearance, the diameter of the well, the environment type in the circular clearance (air, water) and the distance from the charge was estimated.

Numerical simulation of the explosion was carried out in axisymmetric formulation under the following initial conditions:

1. Explosive - patronized ammonite No. 6GV
2. The length of the cartridge - 200mm
3. The diameter of the cartridge - 32mm
4. Charge design - solid and dispersed
5. Distance between cartridges - 200, 300 and 600mm
6. Initiation of explosive cartridges - simultaneously
7. The diameter of holes (wells) - 32,76,82,116,126 mm.

The fixation of pressure at the wave front was carried out both at the "water-rock" and "air-rock" contacts, and as it spread into the bulk of the massif.

According to the results of numerical simulation, the pressure of the stress wave from an explosive explosion on the walls of the hole (well) and the nature of its dependence on the size of the water and air clearance, the distance between the cartridges, the location of fixation points from the charge and the distance from the hole contour were determined.

The established regularities of the energy saturation of the massif in the interaction of several charges in the well allowed us to determine such technological parameters of drilling and blasting, such as the specific consumption of explosives and the grid of the location of the wells.

Based on the analysis of the obtained data, the main provisions of the methodology for calculating the parameters of drilling and blasting in the kimberlite breaking of charges with a water circular clearance are formed.

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RESEARCH OF SHIFTS AND DEFORMATIONS OF TERRESTRIAL PO-VERHNOSTI IN THE EARNED ADDITIONALLY TERRITORIES KARAGANDA COAL BASIN

Carrying out excavations involves change of stress of the massif of rocks, causes deformations and their movements towards the developed space that causes emergence and development of process of displacement.

The chosen area of the Karaganda coal basin has feature - the same sites of the land surface are earned repeatedly additionally.

On the basis of the analysis 9 sites (posts) in the territory of the basin which are in a side job zone are allocated. On these posts the system of observing stations, for the purpose of obtaining key parameters of displacement of the land surface was created at its repeated side job.

On nine sites within four years systematic tool observations of the earned additionally sites of the land surface for the purpose of identification of change of size of displacement were made eventually [1].

For a research of deformation of the land surface on earned additionally territories of the chosen area satellite monitoring was carried out.

The analysis showed that after achievement of the maximum size of subsidence there is a stabilization of process of displacement of the land surface in connection with full working off of a clearing lava and filling of the developed space with the brought-down roof rocks [2].

Results of satellite monitoring of displacement of the earned additionally land surface coincide with the taken tool geodetic measurements of the current state of the land surface.

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INFLUENCE OF THE GEOMETRY AND EFFECTIVE STRESSES ON THE NONLINEAR DEFORMATION ZONE IN THE ROCK MASS AT DEPTH OVER 1.5 KM

Analysis of the deformation surrounding geometry, need to take into account all the factors affecting the great excavation. The characteristics of the disturbed area during development depend on the physicomechanical properties of the rock, the method of the dig and the geometry. The original properties of a rockmass or near an excavation were changed after digging, such disturbance can significantly affect the performance rockmass and the production mining. The main factors related to the formation of deformed regions are (a) excavation effects and (b) redistribute stress after excavation. However, the geometry will affect stress redistribution after excavation. Mountaka Souley et al. developed a nonlinear model of the rock mass and applied it to predict the deformation zone development of Garpenberg, Sweden mine with a circular geometric. Simulation 2D and 3D has been made to model the first phase of the mining process, compared with real results. Diederichs et al. listed major factors affecting the interaction of crack near the underground excavation, including scale effect, reduced confinement of position due to open cracks, surface interaction, surface cracks, pre-damage, damage due to rotation and heterogeneity stress.

For the purposes of this study, three different geometries (square, circular, horseshoe) were evaluated in order to understand their effects on the formation of the nonlinear zone in a rockmass at a depth of 1500 m and the direction of

stress on the production excavation according to three situations: Maximum stress parallel to the axis of production excavation; Maximum stress perpendicular to the axis of production excavation; Maximum and minimum stress were created with the axis of production excavation was an angle 45 degrees.

The discussed results show that effects in the geometry of excavation, circular or horseshoe, had a more pronounced effect on reducing the propagation of distortion in the roof area when a generation was aligned with the horizontal capacity in a small plane (perpendicular to the direction of maximum compressive stress). Wall side deformation was obtained relatively unrelated to the geometry of production. This study continued to confirm the remark that the rounding at the roof of the excavation effectively reduced the spread of deformed areas around the excavation and along it was the entire length of the roof. Finally, the v-grooves were again recorded to form in the direction of maximum compressive stress, regardless of the geometry of excavation. The presented results of three-dimensional modeling show that the alignment of the axes of generation by the primary and secondary stresses in the plane was again the dominant factor in the development of the zone of generation deformation. The rounded geometry of the roof compared to square geometry reduced the size of the V-shaped grooves as a result of the favorable flow of stresses. However, studies of horseshoe geometry with changes in the radius of a circle on the roof under development conditions are necessary for further study in order to reduce the deformation on the roof as well as the displacement of the earth's surface.

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EVALUATE OF THE ACCUMULATED UNDERGROUND VOIDS HAZARD LEVEL OF THE DEPOSIT "MNOGOVERSHINNOE"

Deposit "Mnogovershinnoe" (MNV) has a complex geological structure, uneven distribution of ore, different stability of ores and host rocks. Mining operations are complicated by closely located existing mine workings. Over the decades of the mine, a significant amount of underground voids has been accumulated. There was an urgent need to conduct special studies of geotechnical processes at the mine and clarify the degree of danger of accumulated underground voids.

Researches of geotechnical conditions of the MNV gold deposit were conducted by the authors in 2012-2017. The basic physicomechanical properties of the rocks, the initial natural stresses of the mountain massif were measured, the technogenic stresses in the mine workings and pillars were measured, the factors most influencing the stability of the mine workings were determined [1,2].

In the process of research, a method was developed to rapid evaiuation of the underground voids stability degree. In accordance with the methodology, the most dangerous underground voids with complex geotechnical conditions are first identified. The maximum calculated values of technogenic stresses on the contour of the investigated voids are calculated, the strength properties of the surrounding rocks are specified. Then, on the basis of empirical-statistical dependencies, the estimated time of steady state of the underground void is determined. Depending on the ratio of the actual and the estimated time of service of underground workings, the degree of its danger is established.

After the estimated time, it is advisable to extinguish the identified dangerous underground voids with known methods: maintenance, localization, partial laying and controlled self-destruction.

According to the research, a number of regulatory documents on the management of geotechnical processes have been developed, which are implemented at the MNV.

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ESTIMATION OF GEOTECHNICAL CONDITIONS OF THE SHIKHANSKY AND NOVO-BAKALSKY DEPOSITS OF SIDERIT

The Novo-Bakalsky and Shikhansky fields developed by the Sideritovaya mine have been in operation since the mid-20th century. The fields have complex geotechnical conditions: a wide range of strength properties of rocks and ores, a high level of natural stresses, the presence of nearby open-pit workings, the accumulation of a significant volume of underground voids.

In 2005, the Urals Branch of the VNIMI developed a Conclusion on the tendency of deposits rocks and ores to the occurrence of rock bursts [1]. Since 2008, the monitoring of the geomechanical state of the rock mass has not been carried out. There was an urgent need to clarify the geotechnical conditions in order to assess the danger of rock bursts in deep mine horizons in accordance with the requirements of the Regulations [2].

During the research it was revealed that significant gravitational-tectonic stresses act in the rock mass of deposits. Rocks and ores are characterized by high elastic and strength properties, prone to brittle failure under load. Engineering calculations and field measurements of technogenic stresses in mine workings and pillars are made. It has been established that the preparatory workings of the lower horizons of the Siderite Mine are in a stable condition. Identified unstable state of the pillars. After extraction of the main ore at the working block, these pillars are recommended to be extracted.

Due to the fact that there are no external signs of shock hazard of rocks and ores on the field, at the deepest horizons (290 m), at the current moment the field is classified as unwilling by rock bursts. However, considering the presence of high gravitational-tectonic natural stresses, the seismic characteristic of the area, the presence of rocks prone to brittle fracture, it is recommended to monitor the geotechnical state of the rock mass at the mine in order to timely detect dangerous manifestations of rock pressure in dynamic forms.

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SEISMIC IMPACT EVALUATION WHEN DEVELOPING UNDER THE SETTLEMENTS DEPOSITS, FORMATION PRINCIPLES OF SAFETY BLASTING OPERATIONS

The report discusses methods for evaluating seismic effects during mining of ore bodies located directly under the settlements, presents the results of actual measured seismic velocities on protected surface objects with the subsequent formation of safe blasting parameters at Uchaly MPP.

The presented methods for assessing the resistance of buildings and structures to seismic vibrations were determined in accordance with the rank classification for protected surface objects in accordance with SM (safety manual) G-05-039-96 “Guidelines for analyzing the danger of emergency explosions and determining the parameters of their mechanical action”.

For a comprehensive assessment of the permissible seismic velocity, the requirements of GOST R 52892-2007 “Vibration and impact. Vibration of buildings. Measurement of vibration and evaluation of its impact on the

structure ", with a short-term vibration at the limiting value of the vertical component Vz (vertical component of the peak value of speed).

When developing safe blasting parameters, the conditions for the need to reduce the charge mass in the deceleration group were taken into account in accordance with the correction factor that takes into account the multiple repetition of explosions (Table 1).

Table 1 - The coefficient of reducing the charge mass in the group, taking into account the repetition of explosions.

The number of explosions in the calendar period (year) is	<10	<50	50-100	100-250	250-500	>500
The number of explosions in the calendar period (year) is	0,98	0,9	0,72	0,64	0,56	0,50

On the basis of instrumental seismometric studies and results obtained in the period 2017-2019, the safe parameters of blasting operations are presented, and the reasons for the occurrence of existing cracks and minor deformations of protected objects before the blasting impact on the surface objects under study are assessed.

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ON THE PREDICTION OF THE OPEN PIT SIDES STABILITY IN COMBINED DEVELOPMENT OF QUANTUM DEPOSITS OF THE SOUTHERN URAL BY THE METHOD OF SURVEY MONITORING

When developing mineral deposits, it is important to ensure continuous monitoring and forecast of the stability of mine workings and to prevent their sudden subsidence, landslides and collapses.

Surveying monitoring is a necessary part of the mine safety system for the enterprise, it allows to control the correctness of the taken security measures and design decisions for setting the sides and ledges of the quarry to the ultimate position, what is provided by the introduction of surveying measurements at the field of the automated station and the implementation of the principle of "instant decision-making" in it.

The automated surveying observation station consists of a LeicaTM50 robotic total station with a control program, a meteorological station, a total station shelter, data transfer to a data storage server, software for processing,

analyzing, informing those responsible and managing warning systems (GeoMoS software), satellite receivers and working bench marks.

The forecast of the state of the rock mass within the observation station is carried out in the software product CREDO DEFORMATION CALCULATION. The program allows you to calculate the values of vertical and horizontal displacements, the curvature of the surface displacement, dilatation, stretching, and compression. It implements a forecasting module based on the construction of a trend line with an indication of the magnitude of the accuracy of the approximation and the assessment of reliability by the Fisher criterion. The most accurate forecasting results are provided when the short-term forecast is performed.

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DEVELOPMENT CONCERNING ASSURANCE OF THEIR SUSTAINABILITY

The development program of Ekibastuz coal field within the Bogatyr and Severny mines provides for a transition to a cyclically-continuous automobile-conveyor technology that will increase the capacity of existing mines, reduce the cost of transporting coal from the bottom to the loading points and make the products quality control system more flexible with the help of projected coal average storage facilities. When designing coal warehouses, it was decided to locate them inside the section on the upper levels of the stationary face. This decision is dictated by considerations of economic efficiency and environmental safety, since the option of arranging warehouses on the earth's surface will require an extension of the mining allotment with all the ensuing registration procedures and coordination with the authorized state bodies, as well as payments for the use of land. However, with all the obvious advantages of this solution, the most important geomechanical factor is not taken into account - the stability of the slopes and the bearing capacity of the upper horizons of the stationary face of the section.

During the last 10 to 15 years, in the area of the proposed construction of coal depots (section 6 of the Bogatyr mine), active landslide phenomena of the stope benches of the stationary face occurred. Deformations of the stope benches (mountains +165 - + 200 m), composed of loose sediments and clay rocks, threaten the implementation of this project.

In this regard, it is necessary to conduct additional studies on the properties of rocks of the upper horizons, establish the causes of landslide events and assess the risks of possible deformations of the considered section of the stationary face at the Bogatyr mine, considering the construction, placement of equipment and loading of sites with a coal pile.

Performed surveys revealed the presence of groundwater and watering of the massif in almost all wells. It is the water cut factor that is the main cause of

the onset and development of deformations in the studied section of the mine face. Therefore, first of all, it is necessary to organize the work of the drainage system, in order to exclude moisture from weak clay massifs of the upper horizons and rock contacts. To prevent infiltration into the meltwater massif, you should constantly monitor the drainage system and organize the drain in the direction of the catchment ditches.

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TRAINING HIGHLY QUALIFIED SPECIALISTS' GEO MECHANICS FOR MINING COMPANIES

The most important condition for industrial-innovative development is training with a high level of knowledge and practical skills in the mining and metallurgical industry. Thus, in the process of mining, special attention should be paid to the safe and rational development of mineral deposits. This is connected, first of all, with the Geo mechanics' training, who are responsible for the correct geomechanical assessment of the massif state, secondly, the introduction of advanced technological solutions for the extraction of minerals and, thirdly, the use of automated production control systems.

In order to achieve this target, we developed a new educational program in the majors course "Innovative technologies in the mining and metallurgical complex: Geotechnics", including modern disciplines aimed at studying the physical processes occurring in the earth's crust, the rock mechanics, the geomechanical support of mining at open and underground development with monitoring, organization of scientific research, geographic information systems in mining, array stability management, recommendations and auditing. For the full-fledged training of geotechnical specialists in the framework of effective cooperation with mining enterprises, the existing potential of the Union of Mine Surveyors of Kazakhstan was used, which allows them quick solving the issues of passing production practices and distributing graduates.

Modular programs and work curricula are coordinated with leading higher educational (scientific) universities (institutes) of the world: Michigan Technological University (the USA), Clausthal University of Technology and the Boit Graduate School of Applied Sciences (Germany), Higher Mining School - Ostrava Technical University (the Czech Republic), S.O. Chinakal Institute of Mining (IM) RAS (Russia, Novosibirsk).

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ASSESSMENT OF OPEN PIT IMPACT ON SURROUNDING ROCK MASS, AND CONDITIONS FOR COMBINED SECONDARY MINING OF FLAT ORE BODIES

When flat ore bodies are remined by a combined method, it is important to know the limits of the open pit influence on the surrounding rock mass, in order to ensure safe extraction of ore pillars using an underground method. At Zhezkazgan deposit, there have been precedents of cutting the rib pillars under the open pit. The simplest elasticity models usually describe the displacements of ground surface and the pit slopes.

Dimensions of zones in which rock mass stress conditions change as a result of open pit mining depend on the pit depth, slope angle, width of pit bottom, initial stress conditions and geotechnical properties of the rock mass. All these factors are independent variables. Their variation limits selected for modeling were determined for the conditions of Zhezkazgan deposit. To describe parameters of the open pit influence zones in the multi-factor space of independent variables, numerical models were constructed using the experimental design theory which allows the modelling options to be minimized. To obtain the simplest linear approximations, the Plackett design was used.

According to the results of the modelling designed as a multifactorial experiment, the maximum slope displacements depend, to the greatest extent, on the pit depth and a horizontal component of the natural stress field. In all models, the maximum slope displacement was observed in a lower third of the slope height and was directed toward the center and top of the pit. Therefore, the maximum displacements caused by elastic rebound of the rock mass volume are proportional to the relieved stress values. The same variables determine the width of a slope destressing zone. Both parameters are independent of the anisotropy, rocks mass strength characteristics, slope angle and the width of pit bottom, and are only determined by in-situ stress conditions affected by open-pit mining. Hence follows an important practical conclusion: the width of a zone of pit influence on the surrounding rock mass is directly proportional to the pit depth and a horizontal component of the natural stress field. Considering that horizontal components generally differ from each other to a great extent, the pit influence zone will be much wider in the direction of the maximum tectonic stresses.

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GEOTECHNICAL CONSIDERATIONS FOR MASS MINING – A CHILEAN EXPERIENCE

As a result of technology advances in the last decade, the international mining industry has taken an increasing interest in highly productive and low-cost methods of open pits and underground mass mining. This has brought with it increased interest in steeper and deeper pits, and block/panel caving methods; and in their application in mining environments that are different from, and more challenging than, those for which were originally developed. Many of the challenges currently being faced in the planning and operation of deeper pits and block/panel caving mines, arise because of the high rock mass qualities of the orebodies being mined, transition between open pit and underground methods, the greater depths at which caving is being initiated, the associated problems of extraction level stability, and the increasing heights of the caving columns.

Rock engineering is a key factor in the optimization of the open pit and underground mining business. Today, most mines are considering deeper and steeper rock slopes, which can only be achieved by sound geological and geotechnical engineering, and a team work focused on slope monitoring and management. In addition, mass mining options, such as autonomous haulage system (AHS), in-pit crushers and conveyor belt systems need to be incorporated into the geotechnical design and acceptability criteria. In underground mines, the implementation of big LHD, large cavern and excavations for hybrid or sizer crushers require a special and robust geotechnical design and support requirements.

This paper reviews the current state of the practice in Chilean open pit mines and underground mass mining, with emphasis on the definition of acceptability criteria for pit slope design and underground key geotechnical parameters.

INNOVATIVE TECHNICAL AND TECHNOLOGICAL SOLUTIONS

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A NEW WAVE OF INNOVATION IN COMBINED MINING OF ORE DEPOSITS ON THE BASIS OF THE TRANSITION TO SELF-PROPELLED ELECTRICALLY-POWERED MINING MACHINERY*

Combined geotechnology is in itself a condition of the achievement of the highest indices of the completeness and overall efficiency of ore deposit development. The enhancement of energy efficiency of combined mining of solid mineral deposits is inseparably associated with the modernization of production and application of electrically-powered machinery. This characterizes the phased transition to the new wave of innovation in mineral deposit development [1-3].

Actually, the growth of efficiency of mining engineering system operations is based on the replacement of diesel-powered mining machinery with electrically- powered equipment. One of the main advantages of the mine flowsheet with electrically-powered machinery is in the minimization of capital and operation costs of ventilation system and its planning and design expenditures. The new wave of innovation is closely associated with the transition to the application of less energy-intensive main and booster fans, minimization of air cooling and fresh air supply costs in mine workings [4]. Another meaningful advantage for the personnel is the significant improvement of working environment underground, as it has been proved that continuous exposure of mine workers to exhaust fumes of diesel engines and finely dispersed aerosols in the mine air produce a harmful effect on their health [5, 6].

The analysis of data on the operation of 30 mines developing ore deposits has resulted in the development of the mathematical relationship of the effect of ICE exhaust fumes volume on costs of mine ventilation system operation. It has been found that the annual operation costs of a diesel-powered loader are 2.8-fold higher than those of an electrically-powered loader of the same loading capacity and equal operation hours. In the comparative assessment of the two drives of mine machinery with the same performance characteristics, conditions and commands it has been proved that diesel engines emit three-fold more heat to the air of underground workings than electrically-powered mine machinery. This is also proved by the international practice [4]. Electrically-powered mine machinery in operation do not emit harmful gases, aerosols and other harmful substances of any physical state [7].

The transition to the new wave of innovation of the combined mining of ore deposits in conditions of mining engineering systems operation based on electrically-powered machinery requires further research into the design of a

* The studies have been performed within the framework of the ICEMR RAS Research Project 0138-2014-0001

mine electric power system and ventilation patterns providing for the absence of exhaust fumes and improvement of the quality of mine air.

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IMPACT OF REDUCING A MASS INTO NOT BUMP HAZARDOUS STATE ON THE STRESS DISTRIBUTION IN MINE DEVELOPMENT OF KOCHKAR BUMP HAZARDOUS DEPOSIT

To date, mining work at Kochkar gold deposit, represented by a series of rake veins with a great depth of fall and capacity from fractions up to several meters, is conducted at depths of 700, 750 meters, and preparatory works - on the horizon of 800 meters. Lowering the level of work significantly affected the efficiency of field development. The geomechanical situation is significantly complicated with depth, the frequency and intensity of occurrence of rock pressure increases, as ores and rocks are characterized by high strength, a tendency to accumulate elastic energy, and the deposit is classified as bump hazardous.

The foregoing resulted in the search for measures that ensure the neutralization of negative geomechanical factors. For this, an analysis of the mining situation and methods of bringing the mass into a non-hazardous state was carried out.

Long-term intensive exploitation of the Kochkar field led to the formation of a large volume of voids. The established geomechanical model of the deposit is represented by clearing workings formed along the veins, separated by ore and blank pillars. Significant articulation of the rock, the relative low intensity of mining work contributes to the active manifestation of rock pressure, including in a dynamic form. Assessing the impact of rocks by various deformation and energy criteria, confirmed that the rocks of Kochkar field are capable of accumulating elastic energy and are potentially bump hazardous.

According to the results of the research, the main directions for solving this problem were identified, the essence of which is to clarify the parameters of the development systems and improve their structures. In this case, it is obligatory to carry out preventive measures in the form of unloading the rock from the accumulated deformation energy.

The conducted simulation of measures aimed at bringing the mass into a non-hazardous state in the software package based on the finite element method showed their effectiveness.

At the moment, the parameters of these events are being updated to improve the quality of mass unloading and reduce the cost of their implementation. In the future, they will be tested in the most dangerous areas of Kochkar bump hazardous field.

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ABOUT THE APPLICATION POSSIBILITY OF THE UNDERGROUND EXTRACTION TECHNOLOGY USING «ALIMAK» COMPLEX AT THE KOCHKAR FIELD OF SC «UZHURALZOLOTO»

The decrease in the level of mining at Kochkar vein field is accompanied by a decrease in the content of useful components, complication of the geo mechanical situation, manifested in an increase in the frequency and intensity of manifestations of rock pressure in a dynamic form, and, consequently, the rising cost of production and transportation.

The foregoing necessitated the search for measures that would reduce the cost of production and neutralize negative geomechanical factors. For this, an

analysis of the mining situation, the state of the raw material base, and the current trends in the improvement of mining technology was carried out

Of all the development systems used at Kochkar field, three are most widely used: sublevel drifts, with a store and with a hydraulic folding. In recent years, the development system of sublevel drifts has been mainly used, which is explained by the lower cost of production. All development systems include the use of portable equipment and are characterized by an increased amount of Commissioning and Start-up CS.

Given the complexity of the problems facing the company, a complex of research and pilot tests was carried out to design new development systems using the ALIMAK complex and geo mechanically substantiate their geometrical parameters, find ways to utilize cyanated tailings in backfill mixes, and take preventive measures to bring the array in shockproof condition.

The main advantages of the mining system in comparison with the used systems with small hole blasting: work safety; high labor productivity and indicators of mineral extraction from the depths.

The analysis of possible technological schemes for the development of reserves by development systems with increased height chambers showed that mining Kochkar field using the ALIMAK type complex with the subsequent laying is currently cost-effective.

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PUTZMEISTER EQUIPMENT FOR MINING: PASTE TAILINGS, MINING SLUDGE, CONSOLIDATING STOWING

OsadcCleaning up of sludge collectors with PUTZMEISTER pumps

Variable density mine sludge, on average, 1.6 tons / m³ (including stones, wood, etc.) generated during drilling and tunneling operations, is to be pumped by a submersible pump to the receiving hopper of the PUTZMEISTER pump, from where it is pumped in one step over the horizon up to 5 km or with a rise in one step up to 700 m in a volume of up to 200 m³ / h. For pumping, for example, the pipeline D_{ext} = 159 mm with a wall of 5–8 mm is used. The existing drainage scheme does not need to be redone.

Pumping hardening filling pumps PUTZMEISTER

Chambers formed during the development of underground salt and ore deposits represent a great potential hazard, both on the surface and underground. If, in the past, the filling material was lowered from the surface into the mine, it was often carried out by gravity through auxiliary barrels and along ramps, after which the material was distributed using loading devices, material into the area. Due to the availability of modern technology of hydraulic supply of materials, it became possible to improve the efficiency of

exploitation of underground deposits using special development systems, as well as the secondary use of mine fields already decommissioned for ore mining.

The use of PUTZMEISTER pumps allows horizontal and vertical transportation of large fractions with low water content through closed pipelines over long distances to the site of pasty materials, regardless of environmental conditions, and without disrupting the current production process.

In a chamber-and-pillar development system with a bookmark, the field is divided into primary and secondary extraction blocks, usually of the same size, which are developed in a certain sequence. At the end of the development of the primary blocks, a filling material containing a binder is pumped into the cavities formed, followed by the development of the remaining secondary blocks. At the same time, the newly emerging chambers after completion of the work are also filled with a filling material with a binder.

One of the installation sites of the backfill complex used in the sub-rise-laying development with a filling, based on the PUTZMEISTER equipment, is Maleevsk underground mine OOO Kazzinc. Here, the filling mixture comes from the surface CST along the trunk to the expansion tank with a capacity of approximately 30 m3, and then to two PUTZMEISTER pumps, which raise it up the trunk to conduct work on all overlying horizons.

Transportation to the dump of paste tailings on the example of a plant for the production of primary aluminum in Zhengzhou (China)

A special material is a paste with a content of: aluminum tailings of 42–45%, fly ash of thermal power plants 20–22%, low-grade cement 1–3%. Used for pumping: Pump for pumping condensed mass PUTZMEISTER type KOS 2180 with a capacity of 90 m3 / hour, pressure 90 bar with a oil tank with a capacity of 315 kW and two pumps for pumping a condensed mass with a capacity of 150 m3 / hour, 90 bar with a power station with a capacity 630 kW.

The advantage of using this scheme

Reduced water consumption for hydro transport. The paste dries quickly, without being absorbed into the soil and does not become dusty, forming craquelure, it is well distributed over the surface, and occupies a much smaller area of storage.

Pipe wear is reduced due to optimized flow rate and volume pumping. The safe tailings maintenance scheme is determined by the stability of the material and the absence of the danger of breakthroughs of the dams of the sludge storages.

The closed water circulation allows refusing the pump station for pumping the clarified water back to enrichment. Due to the low moisture content of the paste, there is no loss in the form of water vapor from the tailing storage plane.

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CONCRETE PLANTS, MIXERS AND CONCRETE GUNS

What are the main components of mechanized gunning equipment?

Mechanized wet gunning is the most effective method for projects that require large amounts of gunning. It is mainly used in underground works to increase operator safety.

Concrete is fed into the receiving bin of the concrete pump and transported through the concrete line to the sprayed spray nozzle, where it is mixed with compressed air and an accelerator for sprinkling onto the substrate.

Concrete pump: low pulsating for continuous flow of concrete

The concrete pump is responsible for delivering the concrete mix to the sprayed-spray nozzle. Wet guncrete mix is usually supplied using double pumps. The design of the pump involves minimizing the pulsations, and hence the heterogeneity of the flow of concrete, to ensure uniform application of shotcrete. Thus, the required quality and layer thickness is achieved; the rebound of concrete from the surface is reduced.

Gunite gantry: gunning with a large radius

Gunned equipment mechanized equipment targets the flow of concrete to the required place. If it is possible to spray sprayed concrete up to 17 meters away, there is no need for scaffolding or telescopic lifting platforms. In one pass, it is possible to apply up to 150 mm of the concrete mix (using fiberglass).

Concrete, boosters and air are mixed in the spray head and sprayed onto the surface through a nozzle. The design and dimensions are very important for the proper compression of concrete and minimizing rebound. Due to the lack of bulk materials used in dry gunning, the entire preparation process takes place in the mixer as it moves towards the gunning unit. This completely eliminates dusting, which has a positive effect on the work and health of the installation operator, as well as on the gunning process, because visually you can determine the places for applying the mixture.

Air compressor: sprayed and compacted concrete mix

The air compressor is responsible for supplying the concrete mix with the kinetic energy required for spraying and compaction. For this, the gunning concrete must collide with the surface at a certain speed, which is achieved not only by the flow of air supplied by the compressor, but also in combination only with the correct diameter of the nozzle. For example, air flow at a speed of 12 m^3 / min through a nozzle with a diameter of 65 mm does not provide sufficient kinetic energy. However, the same air flow through a nozzle with a diameter of 35–40 mm provides the necessary kinetic energy, provided that the spray is carried out at an appropriate distance (1–2 m).

Pumpset: Accelerator Dosing

In order to obtain the necessary formation of early strength, it is necessary to accelerate the hardening of concrete, which in turn requires the use of accelerators. The dosing unit is synchronized with the concrete pump to ensure dosing according to the flow of concrete at any time.

Control system: the "brain" of equipment

It monitors accelerator dosing and pumping of concrete.

It provides correct and safe operation of the concrete pump.

It collects data for loading and processing.

Remote control: safe equipment control

Using the remote control, the operator can control and change the ratio of the main components of shotcrete (concrete and additives), as well as equipment components (gunning boom and nozzle). Wired and wireless remote controls allow the operator to work while in a safe area.

Motorized chassis: the ability to access the sole development in any terrain

The equipment components are mounted on a motorized chassis that delivers it to the spray area. In confined spaces, characteristics such as dimensions, direction and turning radius are important. Motorization, angles of attack, and rate of movement of equipment are extremely important when processing areas with slopes and on uneven terrain.

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METHOD FOR ASSESSING THE STABILITY OF THE NEAR-SIDED ARRAY DURING UNDERWORKING

The article poses the problem of assessing the sustainability of the quarry near-surface massifs in the development of mineral reserves located beyond the boundary of the career field. During conducting clean-up work from the level of working horizons of the existing quarry with underground technologies, the question of maintaining the steady state of the ledges and sides arises. Undermining the sides of the cuts by underground mines leads to a decrease in the strength of the massif that should be taken into account while determining the total side inclination angles or the angles of the ledges slopes. This effect depends on the system of development, the properties of rocks and the nature of their deformations during part-time work.

The solution to this problem is achieved by defining the boundaries of the deformation zones of the massif during mining operations by using the Stability of single-column columns (BABO) method, described in detail in [1], based on strength certificates, constructed separately for each type of rocks according to the results laboratory research. For the Akzhalsky deposit, the analysis of strength properties in various rocks has been carried out. As a result of the analysis, passports of strength were obtained. According to the strength passports, slip curves were constructed in the rock massif [2]. The values of the angles of displacement for the studied rocks were also established [3].

Based on the data obtained, the boundary of the zone of possible deformations was determined in the conditions of the Akzhalskoye field. The features of the mutual influence of the underground and open development systems when they are combined are revealed, which is of great importance in the design of mining enterprises and mining planning.

The results obtained by using the Stability of single-column columns (BABO) method were compared with the results of a numerical analysis using the Hook-Brown strength criterion. During preparing the initial data for the numerical analysis, the main strength indicator of rocks was the geological strength index (GSI). Refining the physicomechanical properties of rocks using GSI allowed us to establish the transition from the strength of the sample to the strength of the rock mass [4, 5].

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DYNAMIC MODEL FOR SOLUTION MINING CAVERNS

When designing a cavern field, the size of the single caverns and their location is set. Very often, the design shape is a cylinder with a cupola, and the design locations follow an equilateral triangular scheme. But due to various reasons, caverns are very often not cylindrical, and in cavern fields, there will be an interaction, which depends not only on the shape, but also on the distance.

Numerical modelling and stability analysis for caverns is usually done based on single design caverns, i.e. perfect cylindrical cavities. But because of

the deviations from the design, this is not sufficient for most of the real cavern fields. Therefore, a dynamic model has been developed for the simulation of solution mining cavern fields.

The internal shape of the caverns is controlled by annual or bi-annual sonar measurements and is considered in the simulation. The dynamic tool considers the real shape of the caverns and their growth over time, the real geology, topography, geological intrusions, filling with air, brine or mud, and the closure of caverns. The results of the numerical modelling are compared with measured displacements in drifts and show a very good match in the magnitude of the displacements as well as in their distribution. The dynamic model is used for annual stability analyses as well as for prediction simulations, which are used to optimize the future solution scheme from the safety and the economical aspect as well.

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SELECTION OF MINERAL SEPARATION METHODS IN COMBINED DEVELOPMENT OF COPPER DEPOSITS OF ZHEZKAZGAN REGION

Intensive development of copper ore deposits in Zhezkazgan region led to a quantitative and qualitative reduction in the mineral resource base. In terms of the content of valuable components, the commodity ore of the collapsed and weakened sections of Zhezkazgan deposit with a copper content of up to 0.30% is a very poor raw material in copper. The economic feasibility of developing such deposits largely depends on the possibility of using low-cost and high-performance methods of preliminary enrichment, which allows excluding part of the rock mass from further processing, while improving the quality of raw materials.

In the world practice, technologies of preliminary ore dressing with radiometric methods based on the interaction of various types of radiation with mineral matter are most dynamically developing. In radiometric separation, the uneven distribution of valuable components in pieces of coarse ore is used. In the process of single-step separation, the properties of each individual piece are determined, and individual pieces with a high content of valuable components are separated from the stream and tails with non-conforming content are cut off.

The choice of the pre-beneficiation method is determined by the material composition of the ore, the content of valuable components in the ore, the granulometric composition of the ore, the contrast of the lumpy material according to the content of useful components, matching the intensity of

manifestation of the separation feature to the content of the useful component based on the choice of one of the contrast properties.

A set of scientific studies was carried out with various separation methods applied to the conditions for the development of ores of Zhezkazgan deposit: optical (photometric), induction radio resonance, X-ray radiometric (X-ray fluorescence), and X-ray absorption. In the course of the research, the values of the separation feature for each method were determined and their performance and efficiency were evaluated.

The studies made it possible to establish that large-portion sorting in transport tanks by the X-ray fluorescent method using underground ore monitoring stations is fundamentally possible for preliminary enrichment of sulfide copper ores of Zhezkazgan deposit. For conducting semi-industrial tests, a combination of the above described method of large-portion sorting in transport vessels and point-of-time separation based on the photometric method is recommended as the simplest and most productive ones that can be effectively used in the placement of an underground automated ore control station for preliminary enrichment of ores from collapsed and weakened sections that have It contains a large amount of ore mass diluted with brown aleurolite.

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EXPERIENCE IN IMPLEMENTING HEADING-AND-STALL METHOD AT THE AIKHAL MINE

During 2015-2016, the reserves of the trapezoidal chambers of the transition zone with a height of 10 meters were fully developed at the SEDT.

Constructive design of the development system in the seizure of stocks of trapezoidal chambers of the transition zone is presented in Fig. 1.

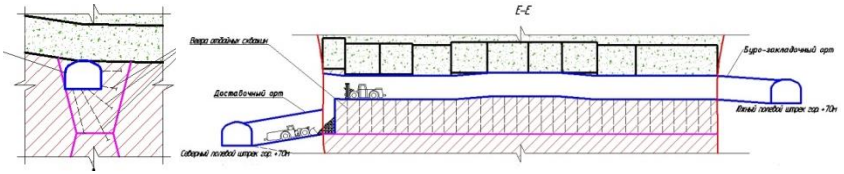

Fig. 1. Design of the development system for the reserves extraction by trapezoidal chambers

The stability of the developed space of these chambers was ensured at all stages of their excavation.

The roof of the chambers, represented by a filling mass, formed in the worked-out space of previously exhausted layers, remained stable and had a flat shape without forming a roof or any significant filling loose.

When excavating reserves of trapezoidal chambers of the transition zone, most likely due to a significant shrinkage of the filling mixture, under-fillings from 0.2 to 0.5 meters was formed in the roof of the worked-out space.

In 2016-2017, at the SEDT, they began to excavate the diamond-shaped chambers of the transition zone with a height of 20 meters. The structural design of the development system during the extraction of trapezoidal chambers reserves of the transition zone is presented in Fig. 2.

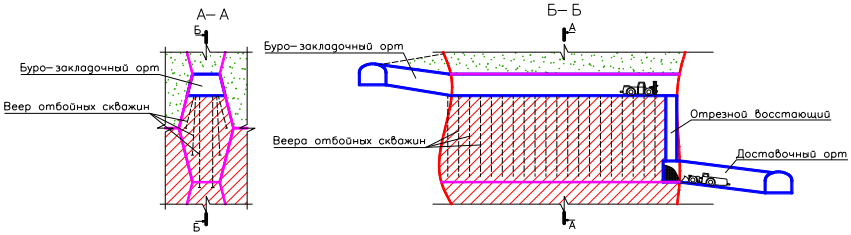

Fig. 2. Design of the development system during the reserves extraction of rhomboid shape chambers

The above voids (under-fillings), formed in the roof of the trapezoidal chambers of the transition zone had a negative impact on the reserves excavation of primary rhomboid shaped chambers with a height of 20 meters, adjacent to the spent trapezoidal chambers. According to the data of visual and instrumental observations in the course of drilling and blasting operations, due to the seismic impact of the explosions, the filling mass was partially deformed in the direction of the formed voids (under-fillings). Deformations are expressed in spalling phenomena of the filling, the appearance of cracks, which open up during repeated seismic effects.

During the transition to the rhomboid-shaped chambers of the lower-lying sublevel due to the displacement of chambers relative to each other by 10

meters, there are no under-fillings in adjacent chambers, deformations (blocking and cracking) of the fillings are insignificant and are not visually fixed. That is, in the absence of a free surface above the filling, seismic waves do not create spalls.

Considering the data above, it can be concluded that the excavation of the rhomboid-shaped chambers of the transition zone adjacent to the unfilled trapezoidal chambers is the most difficult stage of ore excavation. When they are mined to reduce the dilution of the ore mass by blasting operations should be carried out with the introduction of intra-radial decelerations to limit the seismic impact of blasting operations on the stability of the developed space of the chambers.

Conducting blasting operations in rhomboid-shaped chambers strictly according to the developed drilling and blasting passports helps to ensure the stability of the chambers at all stages of their development. Photos of the developed space of rhomboid-shaped chambers are presented in Fig. 3

Fig. 3. The developed area of the rhomboid-shaped chamber (upper and lower sides)

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DISRUPTIVE INNOVATION DEVELOPMENT FOR RESERVES MINING OF YAKOVLEVSK HIGH-GRADE IRON ORE DEPOSIT

Yakovlevsk deposit mines rich iron ores with useful component content in the ore of over 60%. More than half of the ore mined at the deposit is represented by loose differences with a temporary compression resistance of less than 2 MPa. Considering the need to maintain the upstream rock mass in a steady state due to the presence of aquifers, as well as the extremely weak strength of a significant part of the ore, a layered mining system with a hardening tab and with a descending order of excavation was adopted as the main development system.

Poor performance of the standard version of the layered development system currently used; and the need to increase annual production at the mine required the search for more productive options for development systems.

The positive experience of introducing rhomboid-shaped chambers in the conditions of the Aikhal mine of PJSC ALROSA, whose ores are of low strength, proved that even in the conditions of Yakovlevsk deposit, it is possible to introduce fundamentally new variants of development systems with modified geometry of excavation units.

The results of value calculations of a stable vertical jud wall showed that in the conditions of Yakovlevsk deposit in extremely weak ore types the vertical jud wall height of 4 meters is unstable. The results of the calculations are confirmed by the actual state of the ore walls of the excavation skipping, when, during the course of cleaning works, ore is shed from the side walls, and there is a need for their attachment.

Under these conditions, by analogy with the Aikhal mine, the best alternative is the option of staggered positions, when their mutual position allows for the extraction of ore reserves with the highest possible geometrical parameters. This is achieved due to the fact that during the formation of the clearing space, the upper half of the excavation step is located in the backfill array of previously spent visits, and the lower half is buried in the ore massif. In addition to increasing the vertical height of the excavation unit in conditions of weak ores helps the slope of the side walls.

The following parameters were obtained when calculating the rhomboid-shaped approaches: the width of the soil and the jud roof is 5 meters as in the standard layer approach. The angle of inclination of the jud wall α was set close to the slip angle of the loose ore differences, which is α'= 61.5 ° - 62 °, α = 63 °. The results of the calculations showed that the inclined ore wall in the rhomboid-shaped jud 10 meters high is stable for all types of weak loose ores. Verification calculations of the height of the inclined wall of the jud, made

according to the formulas of the physics of soils, confirmed the correctness of the choice of the parameters of the rhomboid-shaped jud.

Therefore, when mining the reserves in a chessboard manner, the rhomboid-shaped jud for the conditions of Yakovlevsk deposit were taken to be 10 meters high, 5 meters wide at the base, and 10 meters wide in the widest central part. With these linear dimensions of the jud, the angle of inclination of the ore walls, and the walls consisting of the filling mass, is 63 °. Due to this, the transverse area of the removed jud increased from 20 to 72 m2.

Based on the results of calculations, as well as mathematical modelling for Yakovlevsk mine, various versions of a layered development system with rhomboid-shaped skipping, worked out in a chessboard manner, were developed. The seizure of the modified shape within the layer is carried out in a chamber-one-piece order according to the scheme 1-2-3-1.

The main advantages of the layered development system with the excavation of reserves with rhomboid-shaped jud in the chessboard manner of mining reserves are:

- No need for carrying out of the mine workings in the ore massif within the boundaries. Accordingly, the construction of metal-intensive arched types of lining, which, in addition to the high cost of mounting, significantly reduces the speed of excavation, which affects the intensity of ore excavation at a particular site (when installing metal arch support, a high proportion of manual labour).

- A drill-laying drift (ort) in the stowage path passes through the ore massif directly under the bearing layer of the filling formed in the upstream spent stopover. In such conditions, the stability of the walls and the roof of the ort does not cause concerns, the fastening with arches is not required (if necessary, anchoring is provided).

The introduction of improved versions of the layered development system for the conditions of Yakovlevsk field will significantly increase the mine productivity and increase the safety of mining operations.

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UNDERGROUND MINING METHOD RESEARCH FOR GRANULAR QUARTZ

Kyshtym deposit is the only large-scale granulated quartz deposit in Russia. The mining technology used earlier at the mine is characterized by a low level of extraction (losses in the subsoil are 28%). In order to save high-value raw materials, comprehensive studies have been carried out, on the basis of which the technology has been developed that combines two classes of development systems in one mining unit. The combined system takes advantage of each individual and provides the maximum reduction in quartz loss. For the Kyshtym field, the best option is a combination of the chamber

dredging of the main reserves of the block with the sublevel collapse of the chamber of a trapezoidal shape.

Experimental tests of the recommended version of the technology in natural conditions confirmed the results of theoretical studies, and their industrial implementation has reduced the technological losses of granulated quartz from 28% to 9%.

In addition to technological losses, a feature of the development of high-value quartz deposits is the loss of raw materials as a result of over-grinding during drilling and blasting operations, which is caused by such properties of quartz as a fine-grained structure (granules 1-2 mm in size) and weak grain cleavage.

The sources of the output of substandard quartz are the zones of grinding and radial cracking. It has been established that reduction of quartz over grinding is possible due to the use of a flat system of dispersed charges. The conditions are determined, the cumulative performance of which ensures its action. The dependences of the yield of the overmilled fraction on the parameters of charge dispersion and the specific consumption of explosives are established. Optimization of the blasting parameters has been carried out, as a result of which the yield of the overgrown fraction is reduced by 25–40% relative to traditional technology.

The economic efficiency of mining by the profit criterion per 1 ton of recover balance reserves increased by 20% due to a cardinal decrease in quartz losses and a corresponding increase in recoverable value.

By reducing the loss of quartz, the conducted research allows expanding the real raw material base of the operating enterprise producing high-purity quartz concentrates and extending the service life of the unique Kyshtym deposit by 18-20 years.

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COMPARISON OF ORE AND FIELD PREPARATION ON A LOW-POWER DEPOSIT AT THE OPENING OF THE QUARRY AND UNDERGROUND MINING OLENOGORSKY MINE

At achievement of profitability of production of iron ore on a pit of a name of the 15th anniversary of October of JSC Olkon, there was a question of application of the combined Geotechnology of production of ore. For this purpose, it is proposed to build Olenegorsky underground mine, making maximum use of the developed space of the quarry, to reduce the volume of mining and capital works. The quarry is a technogenically formed mountainous terrain, which is favorable for the opening of deposits by tunnels. At the same time, it is possible to use difficult training instead of field, and pass all the preparatory workings on the ore.

The purpose of this work is to compare the ore and field preparation on a low-power iron ore Deposit at the opening of tunnels from the spent quarry and their penetration through the body of the ore Deposit and underground mining at the Olenogorsk mine.

Application of ore preparation instead of field has advantages, and gives economic effect on the following:

1) saving the volume of passable rock mass, in ore preparation it is 0.61 of the field preparation, and in ore preparation, 100% of the rock mass is ore, and in field preparation, ore is only 56%;

2) reduction of the mine commissioning period, which is 0.53 start-up time compared to field training;

3) savings on the cost of maintaining the mine workings, as the development of the Deposit is in reverse order, and the preparatory workings and do not experience the influence of mining pressure;

4) reduction of losses and dilution, as mining is carried out along the stretch, and not in the cross stretch of the ore body: mining is carried out from one contact with the ore rock, which provides a smooth and stable character of the ore; and in the field preparation, there are forty contacts with the ore rock.

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SAFE TECHNOLOGY FOR THE CONDUCTION OF EXPLOSIVE WORKS ON THE KARAGAISKIY CAREER IN A CRAMPED CONDITION WITH THE USE OF MOBILE PROTECTION BLASTING SHELTERS OF TIRES DUMP TRUCKS WITH A "RABITZ" GRID

When conducting explosive works in cramped explosive conditions, the most effective way to eliminate the dispersion of pieces of rock and partially the impact of a shock air wave is the use of protective blasting shelter-localizers. Most of the existing types of blasting shelters are mainly intended for sheltering small-sized areas during trenching, ditching, or creating trenches when blasting at construction sites and planning work, but, unfortunately, there is currently not enough experience with mass explosions under shelters. The aim of the work is to develop special mobile localization shelters that prevent the dispersion of pieces of rock to cover blocks that are being prepared for explosive destruction in open-pit mining when blasting operations in cramped conditions near buildings and structures.

A safe technology has been proposed for conducting mass explosions in cramped conditions in the near zone using special mobile gas-permeable safety shelter-localizers against the scattering of rock pieces, new schemes and designs have been developed for attaching gas-permeable safety shelters of

chain-link tires with «Rabitz» grid, that have been tested with an explosive explosion the purpose of checking their reliability and suitability for use in a production environment during blasting operations in the North-West area of Karagaiskiy pit of mining enterprise PJSC "Kombinat Magnezit" in the immediate vicinity of the buildings.

A new method of tying dump truck tires using single-chain chain slings and chains on tires has been applied. When conducting blasting operations at a distance of less than 200 meters from the protected objects, in order to exclude the spread of pieces of rock mass, it is proposed to additionally lay the tires between the rows of blast holes in a staggered manner and closely lay the rows of tires between the blast holes along the contour of the blasting unit. Blasting shelter of tires is covered on top with 1-2 layers of “Rabitz” metal mesh with a cell of 20 x 20 mm, which is fastened with wire to cable or chain cables on tires, as well as to cable or chain slings.

Tire dump trucks are the most versatile in use and much more mobile and cheaper than other types of localizers, they are easily transported, they can cover the blasting area of considerable size. Unlike shield blasting shelters, tires are able to withstand a greater number of explosions due to elastic rubber, they are easily mounted on an exploding unit and do not require heavy-duty vehicles for installation. Blasting shelters consist of detachable segments that allow convenient installation before the explosion and convenient disassembly after the explosion at the collapse of the rock mass.

The disadvantage of this type of blasting shelter is an increase in the complexity of the process and the time of preparation for blasting, tangling (hooking) the edges of the mesh during installation and its installation, the complexity of monitoring the correctness of installation of the explosive network. Given the identified deficiencies, the blasting shelter of tires with a “chain-link” mesh is suitable for use in a production environment.

At the beginning of 2019, the mining enterprise of PJSC «Kombinat Magnezit» started blasting operations using blasting shelters from tires of dump trucks and a “Rabitz” grid, these blasting shelters almost completely eliminated dispersion of pieces of rocks. When approaching the front of mining operations at a distance of less than 200 meters to protected objects, it is recommended to use solid blasting shelters to fully prevent the dispersion of pieces of rock.

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PRACTICAL EXPERIENCE OF MINE WORKINGS STABILITY MAINTENANCE IN THE CONDITIONS OF THE MINE "ORLOVSKAYA"

In the process of pilot industrial testing, industrial and laboratory studies of the technological features of the combined bolting use on the basis of SRB and the strength parameters of the elements and the technical characteristics of the reinforced combined lining were carried out. Tests of fastening technology using SRB and armokarkas were carried out on the experimental section of the excavation of the mine workings of Orlovskaya mine with mining and geological conditions typical for this field.

The technology of fixing workings using reinforced combined support based on self-fixing anchor lining of friction type (SRB and reinforced frames ensures the creation of a stable contour of workings in rocks of medium and low stability.

The technology of fastening SRB can be applied in the conditions of Orlovskaya mine of OOO Vostoktsvetmet using the existing drilling equipment for the installation of boltings.

SRB-Armokrep should be considered as an alternative for support used in the mine: in the rocks of the II-III categories of resistance - steel-polymer anchor bolts (SPRB); IV category of stability - metal frame of the Heintzmann beam.

In the rocks of the middle category of resistance SRB-Armokrep can be applied both as an independent kind of lining and in combination with shotcrete; for the weak category of stability -SRB-Armokrep only with a covering and bearing layer of gunning concrete, up to 150 mm thick, depending on the purpose and service life of workings; for rocks of very weak resistance - it is necessary to provide for preliminary strengthening.

To improve the performance of fastening and increase the quality of lining during the construction of the gunning-concrete layer to a thickness of 150 mm, it is advisable to use a “wet” method of gunning or it is necessary to improve and technically modernize the existing technology of “dry” construction of shotcrete. That will also expand the conditions for the use of reinforced combined support on the basis of SRB-Armokrep.

In order to ensure the stability of the roof of the joints of the workings, it is advisable to use SRB bolting up to 3 m in length or consider a two-level bolting using the rope method of fastening.

It is possible to provide additional stability of rocks in the construction of mine workings by reducing artificial cracking through the use of contour

blasting during blasting operations, which will reduce the dynamics of the softening of rocks when exposed to moisture.

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DIGITAL TRANSFORMATION OF DETONATION SYSTEMS AND ROBOTIZATION OF THE PROCESSES OF THEIR FORMATION FOR THE ENHANCEMENT OF DESIGN EFFICIENCY AND SAFETY-IN-BLASTING

In the current situation in mining the enhancement of design quality is provided by the system approach covering modeling and design with due account for technological, mining and geographic factors, and monitoring of blast parameters and results, prompt updates to the design with the use of software products with the collection of statistical data allowing blast parameter measuring and optimization of results due to drilling and blasting parameter updates based on blast results /1/. Currently the available specially-designed software products provide for survey coordinates import and export, scanning of bench section and hole deviation, automated analysis of hole delay and deviation, and blast energy. For monitoring of blasting processes quality the respective images are analyzed with the help of specially designed software; and fragment-size distribution of broken rock is estimated with the construction of cumulative distribution function curves for broken rock and grade yield; blast seismic effect and blast wave data are also analyzed. Design approaches are selected and corrected with due account for the system of tasks and criteria ensuring the maximum value of services due to the enhancement

of blasting process quality, with due account for the efficiency of broken material loading and transportation, efficiency of the material crushing and recovery of useful component, applicable restrictions of blast and blast wave seismic effect, variation of harmful gas concentrations.

IPKON RAS research into the patterns of fragmentation by various industrial explosives with the use of composite simulation models and field tests, and analysis of blast seismic effect have shown the importance of taking into account of the actual rate of energy release and detonation front propagation in the design of drilling and blasting parameters and prediction of fragment-size distribution of broken rock /2/. For the calculation of the least resistance line, reasonable distance between boreholes and blast seismic effect with due account for the actual rate of energy release of column charges of industrial explosives the respective equations have been composed. Work is under way on the development of digital models of the explosibility of industrial explosives and their shattering capability depending on the main contributing factors (density of explosives, charge diameter, distance to a charge, rate of energy release, specific consumption of explosives). This work is based on the processing of results of full-scale tests and field studies with the use of composite simulation models taking into account zones of blast effect. The IPKON RAS researchers have developed a series of granulated mixed explosives based on the use of rubber goods processing wastes. Now these explosives undergo trials at mines run by the SUEK AO /3/.

IPKON RAS researchers develop novel geotechnologies for the enhancement of safety and efficiency of rock fragmentation, robotized technology and a mobile robotized platform (plant) for the formation of charges and detonation system intended for rock fragmentation by blast /4,5/ . Application of novel technologies will minimize the number of blasting personnel, dangerous product storage and transportation costs, provide for the non-presence of borehole charging personnel in danger zones thus enhancing safety-in-mining. The proposed technology is intended for the fabrication and application of novel explosive compositions with variable explosibility characteristics and energy density providing overall automation of production based on a robotized mobile platform of borehole charge elements, as well as minimization of industrial explosives consumption due to the enhancement of chemical conversion in the zones of unstable detonation (near the priming cartridge in the hole or blasthole mouth). Within the framework of the Skolkovo Innovation Center Project implementation the TezNaNova OOO is developing emulsion-based compositions of cartridge-packed emulsion explosives fitting the application of robotized detonation systems, technology of the formation of charges with variable explosibility characteristics.

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INDUSTRIAL TESTING OF INNOVATIVE PROTECTIVE COATINGS FOR ROOF BOLTING

In world practice, for the production of anti-corrosion coatings on steel products operated in underground conditions, various powder polymeric materials are used to ensure the long-term and reliable protection of metal structures against corrosion.

So far, bolting, manufactured by OOO UralenergoResurs, was covered with paints based on epoxy and epoxy-polyester resins due to their relatively high chemical and mechanical resistance.

When using powdered high density polyethylene, higher corrosion resistance is achieved: a) compared to paint, it has an increased chemical resistance in aqueous media of different acidity and provides more reliable metal protection; b) more elastic and less prone to tearing when installed in the

hole. Depending on the application conditions, the thickness of the polyethylene coating on SRB (self-attaching roof) may be 500-1000 microns, which provides enhanced insulating protection of anchor bolts against corrosion. Polyethylene thick-walled coatings are recommended for use in soils and highly corrosive liquid media according to CR 28.13330.2017 "Protection of building structures against corrosion. Updated edition CRaR 2.03.11-85" and GOST 9.602-2016 "USCAP" (Unified system of corrosion and ageing protection). Underground structures. General requirements for corrosion protection.

The purpose of the pilot-industrial tests (PIT) is a comparative evaluation of the corrosion resistance of polymer anchor roof linings with a coating based on epoxy-polyester resins and a coating of high-density polyethylene, as well as testing the carrying capacity and the performance of SRB and PBS bolting - protected bolt shaft with a special insert in the form of an PBS bolting of a smaller diameter) with a coating "type No. 1 and with a coating " type No. 2 ".

The main tasks of the PIT are: comparison of the protective properties of coatings of two types according to the following parameters: a) thickness, strength, continuity, insulating properties; b) the nature of coating failure after installation and blasting; c) accelerated corrosion resistance tests under operating conditions; assessment of the carrying capacity of SRB (SRB-PBS protected bolt shaft) with or without a new type of coating.

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THE STUDY OR FILLING MIXTURE PREPARATION ADDING VOLCANIC ASH AS ACTIVE MINERAL ADMIXTURE

For the conditions of Tyrnyauz deposit, the studies were conducted on the use of volcanic ash from the Nartukhuk deposit (Kabardino-Balkaria Republic) as an active mineral additive in the preparation of filling mixtures.

As materials for the preparation of the filling mixture, studies were conducted using the following materials: cement, tailings, water, and volcanic ash.

The tailings obtained at Tyrnyauz deposit are finely dispersed material with a fraction content of -0.08 mm and 65%; -0.04 mm - 46%. Volcanic ash is a compacted material fraction 0-40 mm. The selection of compositions of hardening filling mixture using volcanic ash was carried out on different fineness of ash grinding (25, 45 and 60% of the fraction -0.08 mm). In laboratory tests, cement of class CEM II / C-A 32.5H GOST 31108-2016 was used. Cement consumption ranged from 100 to 300 kg / m3 in increments of 50 kg / m3.

A selection of filling mixtures was carried out without using ashes and with differently ground ashes. The compositions were selected taking into account the rheological properties of materials. In the prepared mixtures, the density and flow ability were determined, which on the Suttard viscometer averaged 24.5 cm (spreading angle 5 ± 2 °). Standard terms for setting bookmarks are 28, 90 days.

The analysis of the strength tests results showed that adding ash to the composition of filling mixtures significantly increases the strength. So the difference in strength between the compositions on the tails without the addition of ash and tails with the addition of ash ranges from 17 to 52%. With a cement consumption of 100 kg / m3, the difference is 52% with the like. 25%; 51% - with the like 45%; 50% - with the like 60%. With cement consumption of 200 kg / m3, the difference is 36%, 37%, 17%, respectively. With cement consumption of 300 kg / m3 - 49%, 41%, 37%, respectively.

In conclusion, it should be noted that the materials commonly used as an additive to filling (granulated slag, ashes, anhydrite) are absent in Kabardino-Balkaria Republic. The material under study is volcanic ash, can be used in the production of filling operations to reduce their cost (savings in cement consumption from 40 to 240 kg / m3, depending on the required strength).

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THE MODEL AND PARAMETERS JUSTIFICATION OF DIESEL FUEL DELIVERY INTO MINE

The increase in demand for copper-pyrite ores in the Russian Federation and on the world market is accompanied by an increase in the production capacity of underground mines to 7-10 million tons per year or more. This, in turn, leads to an increase in the depth of development to 1,500 meters at domestic mines, as well as the length of inclined congresses of more than 10 km, for example, at Gay underground mine.

The latter leads to the complication of the main and auxiliary technological processes with dredging of opening trunks, penetration of the inclined congress, increasing preparatory-rifled and cleaning works with the use of various development systems and self-propelled machines with internal combustion engines (ICE) as the main means of mechanization of preparatory-rifled, clearing and ancillary work.

A significant reduction in the cost of ore mining at an underground mine is possible through the development of a diesel fuel delivery model with an annual consumption rate, for example, at Gay underground mine more than 3,895.0 tons / year or 10.67 tons per day. The increase in the volume of delivery of diesel fuel to the mine requires a radical decision on the choice of the model of delivery of diesel fuel to the mine: by tankers (DF) at the ramp; pipeline installed in the borehole; on skip trunk in special trolleys; the combined method according to the scheme "tanker-well" or "tanker-trolley".

In the course of studying the models of diesel fuel delivery to the mine, the following underground mines-analogues were identified: Gay, Oktyabrsk, Nikolaevsk, Uzelginsk at the operating MPP of the Urals. The study of technical literature on the methods of delivery of diesel fuel to the mine showed that information on the delivery of fuel and lubricants to the mine at the mines is not freely available. The likely reason is the lack of a scientific component in this matter, which is solved by the design departments of mining enterprises.

In order to optimize the model of delivery of fuels and lubricants to the mine, studies have been carried out and an assessment has been made of the existing schemes for the delivery of diesel fuel to the mine at Gay underground mine and underground mines-analogues. Two competitive models of combined diesel fuel delivery to the mine at Gay underground mine — a tanker truck and further along a pipeline mounted in a borehole and in special trolleys along the cage shaft — were developed and recommended.

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MANAGEMENT DECISIONS JUSTIFICATION FOR DIESEL FUEL DELIVERY INTO THE MINE

The relevance of management decisions on the diesel fuel delivery to underground mines is explained by the increase in copper-pyrite ore mining volumes to 6-10 million tons per year in Gay, Uchaly and other mining and processing complexes and in regions of the Russian Federation. The increase in production is accompanied by a decrease in the copper content in the ore to 1.8% at a number of mines and an increase in the cost of mining 1 ton of ore, the cost of which up to 35% is accounted for diesel fuel (DF).

Justification of management decisions for the diesel fuel delivery into the mine was made in order to find the optimal model for the diesel fuel and other fuels and lubricants delivery (hereinafter - fuel and lubricants) to the deep horizons of the underground mine (further description - to the mine) with the development of recommendations for designing the optimal delivery module . The latter is achieved by comparing the competitive options for diesel fuel delivery into the mine: by refueling tankers (hereinafter referred to as RT) via an inclined exit, through a pipeline laid in a cased well and in specially equipped mine cars, with a reasonable choice of the optimal model.

According to the results of the research, a method of rational organization and management of diesel fuel (DF) movement based on the movement of material and logistic flows on the principles of the logistic concept, rochrematic and management has been developed. The application of logistic principles on the delivery of diesel fuel to the mine provides a reduction in the cost of transporting both ore and diesel fuel using self-propelled machines with internal combustion engines (ICE), delivery time to the consumer at a given level of quality and transportation services.

The final criterion for the substantiation of management decisions for the delivery of diesel fuel to the mine was determined in relation to the conditions of the Gay underground mine of PAO “Gaysky GOK” taking into account the factors affecting environmental, social, fire and sanitary norms and rules.

Approbation of the developed technical-economic-mathematical model and methodology for calculating the parameters of delivery of diesel fuel to the mine are presented in the diagram of the model combined with the results of the calculation of parameters in tabular form. According to the calculation of the parameters of the delivery of diesel fuel to the mine for the main and alternative delivery models, the graphs of the cost of delivering diesel fuel to the mine using competing and alternative options have been identified and

constructed. Calculations based on the study of the use of the module for delivery of diesel fuel to the mine in a special trolley, placed and lowered into the mine in the stand of an auxiliary cage shaft, has capital expenditures equal to 4.8 million rubles, which is less than the cost of well transport of diesel fuel to the mine by 28%.

This requires a detailed study of the issues and the organization of technical and fire safety, both in borehole delivery of diesel fuel to the mine, and in special trolleys in the pit with cage winding.

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ACCURACY APPRAISAL FOR THREE-DIMENSIONAL MODELING USING DEFORMATIONS PHOTOGEOLOGY AT AN ALLOTMENT

The increase in the intensity of minerals extraction from the subsoil led to a significant spread in the underground method of developing systems with the collapse of ores and host rocks. For these enterprises, the issue of assessing the state of the mountain range is relevant.

With the intensification of mining operations, both in area and in depth, the area of the earth's surface increases, which is the subject to considerable deformation [1]. In order to comply with surveying instructions, to detect deformations on the surface of a mine field, it is possible to use remote measurement technologies [2, 3].

The purpose of this work is to assess the accuracy of the data obtained from aerial photography from a quad copter, positioned by an electronic total station relative to the company's filming network. This method of shooting allows you to safely determine the coordinates of images with the required accuracy without being in the danger zone of a possible collapse.

In the course of the study, experimental surveys were carried out, the causes of errors in the proposed method were identified, and a method for assessing the accuracy was proposed. The main sources of errors are the error in determining the direction angle -m_{dir} an., °, the angle of inclination to the horizon - mω., °, and the length of the basis of images - TL, m.

Experimental testing of the method was carried out under the conditions of Sokolovskaya mine of SSGPO SC and a comparative assessment of the obtained data with alternative GPS measurement results was given [4]. It has been established that the proposed method for determining the position of subsidence and collapses provides the required accuracy of measurements of 0.5 m relative to the points of removable justification for surveys of 1: 1000 scale in plan and 0.2 m in height [2, 5].

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JUSTIFICATION OF THE LOCATION PARAMETERS OF THE PAIR-CONTIGUOUS BLASTHOLE CHARGES AT OAO OQO KRUTOROZHINSKY FIELD

The development project of the field envisages the use of RBM (roller boring machine)-250MN drilling rigs and others for drilling wells with a diameter of 150, 190, 220 and 250 mm for mining operations.

Calculations of the location of well charges on the ledges of more than 10 m using small diameter wells of 150 and 190 mm showed that the calculated bench toe burden BTB for large block rocks does not pass on the safety condition of drilling the first row of wells. Therefore, the use of well-paired wells has been proposed.

To determine the rational parameters of the location of paired wells, it is proposed to use the principle of self-modeling, based on taking into account the critical velocity of the displacement of the array in the zone of action of the adjacent paired-together well charges.

The rate of displacement of the medium is associated with the current voltage by the following relationship:

$$V_{\text{сж(р)}} = \frac{\sigma_{\text{сж(р)}}}{\rho_0 C_p} K_{\text{д}} \quad (1)$$

where $K_{\text{д}}$ is the dynamic coefficient.

The condition for the destruction of the environment, its separation from the massif and displacement is the equality or excess of the displacement velocities arising from the explosive loading of the massif to the critical values:

$$V_{\text{сж(р)}} \geq V_{\text{кр}} \quad (2)$$

where $V_{\text{кр}}$ – the minimum (critical) values of the velocity of the displacement of the massif, at which the destruction occurs.

The distance between closely spaced well charges with instant blasting should correspond to the condition of exceeding the total displacement rate of the array with the value of the critical compression rate at each point between the charges.

CURRENT ASPECTS OF COMPLEX AND ENVIRONMENTALLY SAFE DEVELOPMENT OF PROCESSING MINERAL RAW MATERIAL

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GROUNDS FOR A DECISION ON THE MINED-LAND RECLAMATION IN THE MINING OPERATIONS PROCESS IN A PITCH-DIPPING DEPOSIT

Reclamation of mined-lands by open-pit mining in conditions of pitch-dipping deposits always cause particular difficulty in comparison with other types of solid mineral deposits. This is primarily due to the existing approach to the design of the mining system, in which the main purpose of field development is to maximize the efficiency of mining operations by assigning significant amounts of work to a later period. The list of these works includes land reclamation activities. At the same time, the costs of performing remediation work in deep quarries reach up to 30% of the extracted minerals value. At the same time, the main costs fall on isolating the ore body outcrops into the pit wall, strengthening its slopes, including loading, and also flattening the slopes of the dumps and the upper ledges of the quarry with the subsequent formation of a protecting shaft along its perimeter. These activities ensure the environmental and industrial safety of the liquidated facility, both for the period of its reclamation and after the completion of these works.

The design decisions adopted today are designed to ensure only the environmental and industrial safety of mining operations, but not the sustainable development of the mining system as part of the integrated development of the subsurface site in the development of steeply dipping deposits. Unlike flat and sloping fields, when it is technologically possible and economically feasible to conduct mining operations with the formation of an internal dump and parallel reclamation of its surface, in developing steeply dipping deposits it is impossible to restore the land to overstating mining operations without finding alternative solutions for using mining equipment.

Promising solutions for land reclamation in the process of developing pitch-dipping deposits are forming the mined-out space and storing it in an appropriate sequence, differentiated when excavating loose and rocks from an array in order to create techno genic objects intended for the reproduction of alternative energy and disposal of industrial waste and their products. In this case, the created techno genic objects are an independent economic entity, not related to mining, and the land on which they are located is reclamated.

The technical solution for the targeted formation of external dumps, providing parallel land restoration, is to create such a design that provides concentration of the wind flow at a given point in space with the required characteristics for installing the specified points of alternative energy sources. In addition, the creation of receiving tanks for the disposal of industrial waste and their products during the construction of the quarry, when loose and rocky

rocks can be found in sufficient quantities, is also an alternative method of forming a man-made object.

As applied to the developed open pit space, its use during the development of a pitch-dipping field is possible only if a detached site is allocated, where the balance reserves will be fully developed. Such conditions are more typical for small-scale, but not for large fields. Under the conditions of the latter, the most expedient is the intensification of mining operations in the northern part of the quarry with the aim of placing the upper benches in the limiting contour. At the same time, the design parameters of slopes should have an angle in the range of 35-45° at a height of up to 5m, in order to ensure the installation of alternative energy sources.

Technical solutions for combining mining and restoring disturbed lands allows us to simultaneously implement the principles of sustainable development of the mining system and significantly improve the efficiency of the mining enterprise by reducing the reclamation cost and reducing the area of leased land.

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FORMATION AND USE OF TECHNO GENIC SPACE ON THE BASIS OF EXTERNAL DUMPS FOR STORAGE OF THE THICKENING TAILS PRODUCT ON THE EXAMPLE OF GAY MINING AND PROCESSING ENTERPRISE

To date, within the framework of the mining and technical reclamation stage of open pit no. 2, Gay mining and processing plant is storing the current tailings. The receiving capacity of this pit, taking into account the pace of the technical stage of reclamation, plans for the reconstruction of the processing plant to increase its productivity to 9 million tons of ore per year, as well as the intensity of the discharge of current tailings will be completely filled in no more than 4 years. Taking into account the lack of the possibility of building a new tailings storage facility, including in the required timeframe, the

implementation of the reclamation of open pit no. 1 is the most expedient solution ensuring the simultaneous implementation of its reclamation and the environmentally safe disposal of tailings. However, the condition of open pit no. 1 and underground mine workings under it does not allow its developed space to be used without additional measures ensuring the technological possibility and industrial safety of placing the product of thickening tailings and at the same time conducting underground mining. In order to prevent the processing plant from stopping due to the lack of a receiving tank to accommodate tailings, it is necessary to search for solutions ensuring their temporary accumulation for the period of preparation of open pit no. 1 and the beginning of its reclamation to the full production capacity of the mining and processing plant.

As an alternative solution to the storage of tailings, the formation of a techno genic space using the existing external overburden dump to accommodate condensed enrichment products, after the construction of a concentration complex of tailings has been proposed.

As a result of the analysis, the adjacent areas to the industrial site of Gay mining and processing enterprise identified a land plot behind the eastern external dump, suitable for the formation of techno genic space for the purpose of locating tailings. In this case, part of the external dump will be performed as an internal slope of the receiving tank, and the rest of it will be formed using rocks located in this dump. Thus, the body of the enclosing dam around the perimeter of the anthropogenic tank is to be poured from the rocks of the outer heap, and the insulating layer on the surface of the internal slopes of clay rocks. This solution will prevent the spread of condensed product and water into the dam body. Along the perimeter of the techno genic reservoir, the formation of intercepting ditches is provided for the purpose of organizing the collection of water and supplying it to the recycling water supply system of the processing plant.

Taking into account the large area of the created techno genic capacity, free water loss of the condensation product and the volume of surface inputs, to prevent water accumulation and ensure the stability of the enclosing dams, construction of sand ditch wells is envisaged in places with the lowest elevation based on the technology of tailings.

For the formation of anthropogenic space in the form of an open warehouse and its further use for the placement of the product of concentration of tailings provides for the following activities:

1. Removal of soil from the open warehouse and enclosing dams;

2. Formation of drainage ditches for interception and redirection of free water from the condensation product and surface water from the warehouse territory to the circulating water supply system of the processing plant, including through the formation of sand wells;

3. Formation of bund walls from materials of external dump rocks;

4. Waterproofing the slope from the inside of the techno genic space due to the formation of an insulating screen;

5. Placement of a condensation product within a man-made container.

Thus, the formation of techno genic space using external dumps to accommodate the product of thickening tailings allows creating a receiving tank on the territory, which was not originally intended for the construction of the tailings. At the same time, under the conditions of Gay MPE, the maximum usable capacity, based on the available land plot and the parameters of the external heap, is comparable to the volume of developed open-pit mine number 1. Based on the area of techno genic capacity, elevations of the relief and the height of the enclosing dams, the volume of material required for their formation is 25 million m3, which is 20% of the useful volume of the mining equipment being built, which is 126 million m3. The maximum service life of man-made containers will be 50 years. This technical solution is considered as an alternative option and a buffer tank to accommodate the tailings during the preparation period of open pit no. 1 to the technical stage of reclaiming mined-land.

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POSSIBILITIES OF APPLIED MINERALOGY IN CREATING ENVIRONMENTALLY BALANCED GEO TECHNOLOGIES

Rational development of mineral raw materials provides for the maximum possible extraction of both useful and associated minerals, the use of its technological properties, the rationale for mining and processing technologies for ores and / or rocks, the expansion and consolidation of the mineral resource base of existing and planned mining and processing enterprises, the consequences elimination of mining and metallurgical production.

To date, geotechnology geological exploration works are being developed and widely implemented, aimed at the full and comprehensive development of mineral deposits, taking into account in the future the reproduction of the mineral resource base and the elimination of the object industrial development consequences, primarily the negative impact on the environment. In this regard, the technological aspects of the mineralogical study of solid minerals significantly expanded and became not only dominant, but also acquired new

content, which led to the intensive development of applied mineralogy as a whole.

Evaluation of the quality of mineral raw materials, primarily forecasted and conducted in the early stages of geological exploration of the ore occurrence (deposit) further optimizes the management of technological processes during its development, contributes to the creation of optimal integrated environmentally balanced geo technologies. Therefore, the necessity of a systematic approach to mineralogical and analytical studies at different stages of the study of a raw material object is quite obvious.

All information should be stored, accumulated and analyzed in its entirety as detail. Experience shows that mineralogical information obtained at different stages of geological exploration is very useful in solving technological and mining problems arising during its mining or geological and economic reassessment.

The reliability of mineralogical research results is determined by compliance with the requirements of the quality control system, which covers the main elements of metrological support of analytical (including mineralogical) work: requirements for laboratories, quality requirements for sample preparation, required accuracy of analyzes, measurement procedures, standard samples of phase composition and properties minerals, procedures and norms of internal and external control.

An important aspect of mineralogical studies is scientifically-based methodological documents that ensure the unity and the required accuracy of measurements, reliable results with a minimum of material costs. All definitions, regardless of the degree of complexity of the object should be performed in accordance with the methodological documents setting out the method of analysis.

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MINERALO-GEOCHEMICAL FEATURES OF THE TITANOMAGNETIC AND ILMENITE-TITANOMAGNETIC ORES OF THE MEDVEDEV DEPOSIT WITH A POSITION OF THEIR DEVELOPMENT

Most of the titanium reserves of Russian magmatogenic deposits in gabbroids are represented by ilmenite-titanomagnetite ores. The predominance of titanomagnetite in ores is the main reason for their low demand, due to the lack of effective technologies for extracting titanium dioxide from titanomagnetite. Therefore, the most promising deposits with a high proportion of titanium dioxide are ilmenite-titanomagnetite, apatite-ilmenite-titanomagnetite and ilmenite-magnetite deposits.

The Medvedev deposit is mainly represented by disseminated titanomagnetite and ilmenite-titanomagnetite ores with different mineralogical and geochemical characteristics - chemical, mineral and granular composition, degree of conversion of ore and non-metallic components depending on their geological and structural position of mineralization.

The redistribution of siderophilic elements (iron, titanium, vanadium, manganese) over ore minerals reflects their genetic characteristics, which ultimately is the determining factor for choosing the direction of technological solutions.

Impregnated ores are characterized by an insignificant variety of texture pattern due to the uneven redistribution of phenocrysts and types of intergrowths with non-metallic minerals. The structure of the silicate component of the ore is medium-fine-grained, substitutions; the ore is small-medium-grained, interstitial, sideronite, recrystallization. Among the more common secondary processes stands out amphibolization and susurititization. The level and nature of recrystallization of microaggregates of magnetite and ilmenite (titanomagnetite) is determined by different genetic nature and determines the quality of the ores themselves.

Changes in ore and nonmetallic minerals are different; in titanomagnetite ores, the main ore-forming minerals are changed to a lesser extent than in ilmenite-titanomagnetite, which is most clearly seen from the interrelation of specific magnetic susceptibility, microhardness and granular composition of mineral aggregates and has a significant impact on the choice of parameters of beneficiation methods.

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NEW ENVIRONMENTAL RISKS CAUSED BY SUBMICRON MINERAL PARTICLES IN THE PROCESS OF MAN-MADE CHANGES IN THE SUBSOIL

The paper considers new environmental risks due to the formation of a stream of submicron particles in the process of man-made changes in the subsoil. A differentiated approach is proposed to consider the mechanisms of hyperfine rock destruction, as processes in which rock destruction is triggered by redistribution of rock pressure, rock shearing, etc., and processes in which rock destruction is associated with a local dynamic effect on the rock of a drilling tool or explosion [1]. The scheme of possible sources of nano-sized particles is presented for the development of deposits.

It has been established that the mass fraction of highly dispersed particles largely depends on the fractal dimension of the crushed material, which, in turn, depends on the scheme of the disintegration process. The problem of the discovery of the mechanisms of formation of nanoscale mineral particles is indicated.

Evaluations of the results of numerous natural and laboratory experiments performed using the «random balances» method show that with the explosive destruction of rock, the proportion of submicron fractions in the volume of crushed material can range from 0.01 to 0.1 percent depending on the type and mineral composition of rock to be destroyed. In shock-rotational and shock-rotational drilling of these rocks, the share of these fractions is two to four times higher than in the case of explosive destruction [2].

A new idea of the structure of the concept of ecology of mining production is given. The features of the transit and deposition of nanoparticles in the Earth's atmosphere, as well as in the mine atmosphere, are considered. The effect of nanoparticles on human health is evaluated, taking into account their mineral composition.

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MIXED TECHNOLOGY PARAMETERS JUSTIFICATION FOR PROCESSING MIXED COPPER ORES FROM DUMPS

In modern conditions, the development of the ore base of the copper industry is associated not so much with the commissioning of new deposits, but also with the involvement of low-grade copper-containing raw materials in the form of dumps of poor sulphide, oxidized and mixed ores, overburden mineralized rocks, lost reserves in the depths of deposits, tailings , metallurgical wastes, etc. At the same time, the most difficult objects for profitable processing are mixed copper ores stored in dumps at most copper deposits, including in Kazakhstan. This is due to the diversity and different flotation properties of various mineral forms of copper of mixed copper ores, which are secondary copper formations as a result of the oxidation of copper sulfides, the fine structure of ores, significant kaolinization and seritization of the host rocks, a high content of ocher-clay sludge. The peculiarities of the material composition and technological properties of the dumps material predetermine the construction of a technological scheme for their processing based on the combination of the processes of flotation of sulfide and leaching

of oxidized copper minerals for the most complete utilization of copper reserves.

The combined processing technology of mixed copper ores was developed for ores stored in the dump of the Taskora deposit (Republic of Kazakhstan), as for the most typical refractory mixed ores (53% rel. Copper in sulphide, 47% rel. In oxidized minerals). The technology provides for sulphate-ammonium leaching of oxidized copper minerals with the supply of ammonium sulfate solvent to the stage of wet ore grinding before flotation, flotation extraction of sulphide minerals, hydrometallurgical processing of productive leaching solutions obtained by separating the liquid phase of the pulp from the concentrate and tailings of the flotation.

The mode and parameters of the combined flotation-hydrometallurgical technology for processing mixed copper ore are substantiated: ore grinding up to 85% of -0.071 mm class with supply of ammonium sulfate and its concentration in the liquid phase 133 g / dm^3, flotation of crushed ore at xanthate consumption of 60 g / t, foaming agent 35 g / t, pH 7.6 units. according to the scheme of basic flotation and two refining operations of copper concentrate, extraction of copper from productive leaching solution by sorption on Lewatit TP 209 XL cation exchanger, desorption of copper from saturated cation exchanger to a copper concentration of 30-35 g / dm^3 electrolyte coming from copper electrolysis, electrolysis saturated to a copper concentration of 45-50 g / dm^3 of copper electrolyte at a current density of 250-300 A / m^2 and a bath voltage of 2.0-2.5 V. Experimental-industrial tests of the technology for processing waste dumped mixed copper ore showed its high w technological efficiency - total recovery of copper in the copper concentrate and copper cathode exceeded 87%.

The new technological structure, aimed at the integrated development and preservation of the resources of the Earth's subsoil, for resource saving and resource reproduction, involves the development and introduction of new innovative technologies for processing natural and man-made mineral raw materials. For refractory mixed copper ores from dumps, this technology can be developed and successfully tested combined flotation-hydrometallurgical technology.

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SOLUTION TO THE LOSS OF HEAT PROBLEM IN HEAP LEACHING BING

Important, interacting in the process of heap leaching, the parameters are the temperature and frequency of air supply, as well as the speed of its movement in the heap leaching bing. The paper presents studies on the identification of the most effective technological parameters in the heap

leaching of gold-bearing ores. The main technological solutions to the problem of heat loss inside the HL bing in tropical areas were proposed.

The main factors affecting the intensification of the dissolution of metals [2; 5] are the concentration of leaching solutions, temperature, pH (more than 9 for cyanide leaching and less than 2 for acid), oxygen, the presence of other metals and ions in solution. Among them, one can mainly single out the essential importance of the interrelated parameters of the intensification of the heap leaching process of "temperature and oxygen" metals, which influence the rate of dissolution of metal from ores.

The temperature factor is important, therefore, in CV processes, they try to maintain its optimum value (15-25 ° C) in leach solutions and inside the CV bing (Fig. 1).

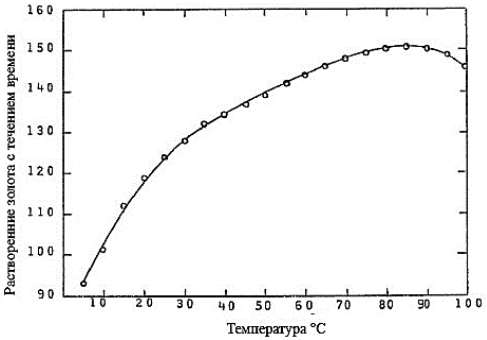

Fig. 1. The effect of temperature on the acceleration of the gold leaching process [6]

At the Veladero gold mine (the borders of Argentina and Chile) with emitters buried to a depth of 150 mm, it was found that the temperature of the outgoing solution was 10–20 ° C, mainly due to the accumulation of heat in the CV stack over time.

Temperatures above 50 ° C make it possible to extract gold from ore containing 2.6% sulfides (pyrite and chalcopyrite), and temperatures above 60 ° C can dissolve gold from sulfide gold ores containing 6% sulphide impurities [7]. This is due to the fact that the solubility of metals increases with increasing temperature. However, with an increase in the temperature of the solutions, with open irrigation methods, the degree of their evaporation increases. In addition, it is necessary to maintain a balance between the temperature of the bing and the solutions and the supplied oxygen from the air.

Increasing the rate of irrigation can also accelerate the saturation of the process solution in the HL bings. However, high irrigation rates can cause significant heat loss. The ratio of irrigation rate to aeration rate also affects the axial temperature.

The supply of sufficient air volume allows continuous oxidation of metal-containing sulphides (pyrite). At the same time, an excessive increase in the rate of aeration contributes to an increased value of heat loss due to gas

advection from the top of the HL bing. So, in order to preserve heat in leaching solutions and an ore pile in the conditions of the tropics, the following operations must be carried out:

- to orient the placement direction of the bing to reduce the effects of radiation, wind and rainy water flows;
- close the bing and deepen the pipelines and hoses under a layer of geo material (sand, clay, geo membrane, etc.);
- use heat-insulating materials (natural or artificial, depending on their economic feasibility);
- to control the heat balance in the solutions and the bing.

Table – The main technological solutions to the problem of heat loss inside a bing of HL conditions of the tropics

№	Name	Dignity	Disadvantages
1	Heap insulation		
	The use of thermal insulation material	Preservation and maintenance of temperature in the bing	High cost of material
	Full or partial thermal insulation of the HL bing massif	There is no need for special preparation of the heap for the rainy season, additional metal extraction	Possible decrease in thermal insulating capacity with time and deterioration of solution leakage
2	Maintaining the temperature of working solutions		
	Close the bing and deepen the pipelines and hoses under the layer of geo material	Saving the cost of maintaining the thermal regime	A slight increase in the productivity of the industrial period in the rainy season

In the implementation of year-round events heap leaching, the capital cost of shielding the piles (to maintain insulation, create a barrier to control the effect of rain, as well as reduce evaporation (see table)) increases significantly [3; 4].

In the climatic conditions of Africa, used in cold regions [1], technological solutions for heating process solutions and the HL bing itself are not required. In addition, they are expensive and economically impractical.

Thus, it was shown that increasing the temperature and increasing the concentration of oxygen on the one hand significantly increase the rate of dissolution of metals.

On the other hand, increasing the temperature will lead to a decrease in the amount of oxygen that is necessary for the dissolution reaction to occur between the solution and the metals.

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MODERN TECHNOLOGIES OF ORE MATERIAL QUALITY CONTROL IN DRAWING INTO PRODUCTION OF LOW-GRADE ORE DEPOSITS DEVELOPED BY COMBINED GEOTHECHNOLOGIES*

High rates of mineral deposit development determine the intensive depletion of reserves occurring at shallow and medium depths [1]. Greater part of promising solid mineral deposits is characterized by low-grade ore reserves, complicated structure of ore bodies, geographically remote location and ore body occurrence at a great depth. Wide-spread transition to greater depths is associated with the development of mining operations turning from surface to underground mining, application of various combinations of physical-engineering and physical-chemical geotechnologies [1-3]. Changing of geological and mining conditions, development of geotechnology combined methods [4] determine the necessity of transition to a new wave of innovation [5]. Based on the results of the performed studies [6-10] one can come to the conclusion that the method of ore underground pre-concentration on the basis of sensor-based geotechnologies is one of the most efficient solutions of the

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current problem. Bulk ore sorting is the most widely-spread method, and its importance is ever growing [11].

Among the available novel solutions one can mention MineSense technologies of which Shovel-Sense solution allows real-time analysis of ore composition due to LHD machinery bucket furnishing with high-frequency electromagnetic and X-ray fluorescence sensors [12]. Belt-Sense technology allows the modification of a continuous conveyor belt in such a way as to immediately get telemetry data on the composition of transported ore in the process of its movement on district or main conveyors from an underground mine to the surface [13].

Along with that, until now, in-mine lump-by-lump separation has not been taken up on a broad scale – in the process of analytical studies only several advanced mines already using or testing this technology have been found. The idea of lump-by-lump pre-concentration is not novel, and it is widely supported by some professional communities, even to the extent of design studies [14], which are based on detailed scientific research [14-17]. In all cases, tests show the opportunity of operation costs minimization, energy saving and enhancement of production efficiency. At the same time, this calls for the turning to a new wave of mine innovation that is often an obstacle for conservative type of mining.

There exist numerous scenarios of pre-concentration, each of which has a number of advantages from the standpoint of productivity, lump-size range, capital and operation costs. Of primary interest for underground separation are the technologies, which are suitable for coarse lump sorting and require minimal infrastructure and space. The analysis of modern separation equipment has shown that in underground ore mine conditions the highest efficiency can be expected from the application of sensor-based ore-sorting lines. Modern compact equipment of advanced manufacturers identified in the course of analytical studies provides an opportunity of underground ore pre-separation on the basis of optical characteristics, X-ray absorption properties, as well as in near-infrared radiation. For underground conditions of non-ferrous and noble metal deposit development the X-ray-based technologies are most suitable.

Modernizing of the available mining systems by way of the integration of these advanced technologies would be promising for significant enhancement of productivity and efficiency of the downstream processes of beneficiation, as well as for energy, water, reagent saving, and minimization of tailings transportation and storage costs.

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BASIS FOR LEVEE FORMATION TECHNOLOGY TO ENCREASE THE RECEIVING TANK OF QUARRY 2 MINED-OUT SPACE AT GAY ORE MINING AND PROCESSING ENTERPRISE

Due to the exhaustion of the useful capacity of quarry no. 2 at Gay Mining and Processing Enterprise and the fact that the mining and technical reclamation of quarry no. 2 cannot be completed with the current tailings of the beneficiation plant supplied as pulp with a weight ratio T: F = 1: 8 and above without changing of the existing hydro geological regime of "Gay" resort and a significant increase in water inflows into the underground mine of JSC "Gay MPP", it becomes necessary to find alternative solutions to increase the receiving capacity of the produced career pit number 2 for placement of tailings. In addition, the possibility of reclamation of quarry no. 1 is conditioned by the need to prepare its worked-out space to accommodate the product of thickening the current tailings of enrichment by forming an artificial security pillar at the bottom and parallel elimination of accumulated voids that are associated with the quarry. The main conditions ensuring the possibility of reclamation of quarry no. 1 as a condensation product are a set of measures designed to block large hydraulic channels through which the product of thickening of tailings can get into protected underground workings.

Taking into account the designated purpose, a method has been proposed for increasing the receiving tank of the quarry no. 2 for its complete reclamation by placing in it the product of thickening tailings, for the period of preparation of pit no. 1. As a technical solution, the formation along the perimeter of quarry no. 2 of the enclosing dam with a ridge mark of 380m was proposed. In order to ensure the environmental requirements related to the prevention of the ingress of condensation product and water from the territory being reclaimed, within quarry no. 2, the clay core is provided for in the construction of the enclosing dam. The impervious and strength characteristics of the formed structure are provided by layer-by-layer erection of the dam with compulsory compaction of clay material and dumping of stale tails in the contact zone with rock formations.

The use of clay rocks from external dumps is provided as a waterproofing material. The main body of the dam is envisaged to form external rock dumps from the rocks.

In order to ensure the minimum volumes of materials required for dam formation and the maximum capacity of the receiving tank, based on the morphometric characteristics of the territory, along the upper edge of open pit no. 2, the spatial position and parameters of the enclosing dam were simulated taking into account the existing road along the eastern pit wall. For ensuring the minimum work on the transfer of the existing road in terms of the area where the enclosing shaft is partially located on it, a solution was proposed to increase the absolute height of the roadway by no more than 5 m with the organization of a curve in the plan with a radius of 30m. This decision will require restriction of traffic on the specified road for a period not exceeding two weeks. For the purpose of environmental monitoring in the southeast, a network of observation wells is envisaged.

Thus, the proposed design, scheme and calendar schedule for the formation of the enclosing dam allows increasing the receiving capacity of pit no. 2 in the period of its reclamation up to the initial elevations, while observing the environmental requirements. At the same time, it is possible to carry out activities for the preparation of the open space of open pit no. 1 for the mining technical stage of its reclamation using the condensation product of the current tailings.

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METHODS FOR MEETING ENVIRONMENTAL REQUIREMENTS IN FOCUSED FORMATION AND USAGE OF TECHNO GENIC QUARRY AREAS

The development of measures to ensure the reclamation of mined-land is an essential condition for licenses for the right to use a subsoil plot. From the technological, economic and environmental points of view, in the industrialized regions of the country, the most promising direction is the storage of industrial waste and their products in the open pit of the mine. At the same time, the effectiveness of this direction implementation is determined by the purposeful formation of techno genic areas in a quarry directly in the process of mining. In addition, this solution allows to fully or partially carrying out the mining stage of reclamation.

Depending on the hazard class and the phase state of the stored materials into the quarry's developed area, ensuring environmental safety requirements can be achieved by using various methods of creating impermeable membrane. Traditionally and widely used waterproofing screens based on clay or synthetic polymers have a number of technological limitations on their use in a quarry due to the need to construct engineering protection systems on large areas of slopes with angles ranging from 15 to 75 degrees.

It is proposed to consider modern waterproofing materials, as well as a product obtained from the waste of enrichment plants, as alternative ways of meeting environmental requirements when creating techno genic containers based on the developed quarry areas.

Modern waterproofing materials, made on the basis of a dry mix consisting of cement, mineral aggregate, reinforcing fibre and modifying additives. When mixed with the required amount of water they form a high-strength non-shrink thixotropic solution. Waterproofing on the basis of such mixtures is provided by applying the method of dry and wet gunniting with the possibility of applying it on slopes with an angle of up to 90 degrees.

Production of waterproofing material based on fluid tailings is ensured by their thickening using flocculant. The results of tests of this material for the conditions of mining enterprises of the Southern Urals show that the nature of the deformation of the tailings treatment product under load is similar to the deformation of water-saturated loams: low water loss at high porosity due to the fact that the formation of flocculant macromolecules on several particles with the formation of polymer bridges in the formation of flocs contributing to an increase in particle deposition rate. In this case, colloidal particles capture water molecules that the soil cannot give up before the destruction of the flocs. At the same time, depending on the particle size distribution of the source tailings and the used flocculant, the filtration coefficient of the thickening product equal to 0.00036 m / day can be obtained, even under loads of 0.05

MPa. This value of the filtration coefficient is significantly lower than the recommended SP 127.13330.2017, in which for the underlying rocks it should be no more than 0.00086 m / day. Since, in accordance with GOST 25100-2011, the soil with a filtration coefficient of 0.005 m / day is waterproof, the thickening product of the tailings with the appropriate technology of their dewatering is a waterproofing material with almost zero filtration.

Thus, by purposeful shaping the open pit mine area to create techno genic containers for the subsequent disposal of industrial waste and their products, in addition to reputable impervious screens, it is possible to create an engineering system for environmental protection using modern waterproofing materials and products obtained by thickening tailings. At the same time, the latter option provides the possibility of simultaneously resolving the issue related to the placement of fluid tailings of the processing plant.

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APPLICATION OF MODELING TRAVEL OF UNDERGROUND WATER IN MINING INDUSTRY: WORK EXPERIENCE INSIGHTS

The new technologies introduction leads to an increase in the depth of development and the scale of underground and open-pit mining. Itasca's specialists have experience at major mining sites, such as the Iron Coal Mine Sashen (South Africa), Chukikamata Copper Mine (Chile), the Venice Diamond Mine (South Africa), the Resolution Mine (USA), the Victor Diamond Mine, and the Jwaneng diamond quarry (Botswana). The huge scale of mining operations at such facilities requires the highest accuracy in assessing the performance of wastewater systems to neutralize inflows and prevent flooding of workings, drainage regimes and also maintain stability of the pit walls.

The report discusses modern approaches to numerical modeling of groundwater movement in the context of open and underground mining. Analysis of practical experience Itasca allows you to demonstrate the importance of the following aspects of hydrogeological modeling:

1. Interaction of relevant specialists in the field of hydrogeology, geotechnics and mining planning.

2. Development of a conceptual hydrogeological model.

3. Selection of programs, algorithms and approaches to modeling.
4. Modeling of underground and open pit mining.
5. Modeling block collapse.
6. Calibration of stationary and transient models.
7. Modeling the dynamics of the formation of career lakes.
8. Predictive modeling of groundwater movement in connection with future planned mining operations and their cessation.

Topical issues such as reasonable requirements for the expected accuracy of modeling, practical application of its results to design wells for drainage systems and drainage and linking geomechanical and hydrogeological modeling data in the process of calculating the stability of the pit walls and modeling the behaviour of rocks in a block or subsurface collapse will also be touched upon.

Finally, the problems of changing the stress distribution in the near-surface massifs in the drying process, which require parallel modeling of rock deformation and groundwater movement, will be considered.

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SUBSTANTIATION OF THE GEOFILTRATION MODELING TECHNIQUE OF COMPLEX DRAINAGE SYSTEMS AT OPEN PIT MINING

The relevance of the work is due to the open-pit development of diamond deposits in the Arkhangelsk region. Hydrogeological conditions of this territory are estimated as complex, which is caused by dissection of several aquifers and complexes by the quarry, with a total conductivity of more than 400 m^2/d. The main role in the watering of the quarries is played by the groundwater of the Padun aquifer complex, composed of layered profile-heterogeneous anisotropic Late Vendian sediments, represented by interbedded sandstones, aleurolites and argillites. In such conditions, given the considerable depth of the quarries (depth more than 400 m), special attention should be paid to the protection of mining works from groundwater.

At the V. Grib deposit of diamonds, taking into account the high values of actual water inflows to the mine workings and filtration anisotropy of sediments, the drainage system consisting of vertical pumping wells and open pit drainage was supplemented with horizontal drainage wells. The main purpose of the construction of horizontal wells is to reduce the groundwater heads near the pit bottom, where aleurolites and mudstones begin to dominate in the section.

In order to predict the change in the technogenic regime of groundwater, in the changed conditions of the drainage of the massif, numerical geo-filtering experiments were performed using the Visual Modflow software package.

As a rule, horizontal drains are mainly used in steeply sloping and vertical bedding, therefore the application of this method under horizontal stratification is in itself new and requires the development of a special modeling technique, with the aim of obtaining the correct prediction result using numerical geofiltration modeling.

The paper presents the results of numerical experiments performed on the Visual Modflow software, aimed at correctly simulating the operating conditions of horizontal drainage wells on finite-difference grids. The main factors influencing the formation of inflow to a horizontal drainage well are determined, the analysis of the influence of the spatial breakdown of the model on the flow rate of the drainage well is carried out. Recommendations on improving the reliability of predictive calculations of horizontal drains, with the use of numerical geofiltration modeling are given.

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OPERATION OF THE HARDWARE-SOFTWARE COMPLEX OF THE AUTOMATED SYSTEM FOR PERSONNEL AND MOBILE MACHINERY POSITIONING AT A MINING ENTERPRISE CONCEPT

Based on an overview of existing industrial safety technologies and new electronic components on the market, the Concept outlines the new requirements to key segments and sub-systems of a system for personnel and mobile machinery positioning in mines.

The concept of the system’s functioning is focused on building of a highly robust fail proof adaptive system for data collection, processing, transmission and display, as well as process management.

The system for positioning of personnel and mobile machinery in mines is a hardware-software complex providing continuous tracking of the personnel and in-mine machinery location at the mine site. It also performs a number of

support functions to provide personnel safety and security and to set up communication lines in underground mines.

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AERO GASDYNAMIC PROCESSES IN POTASH MINES AT REVERSAL OF THE FAN OF THE MAIN AIRING

The emergency when there is a need of reversal of an all-miner ventilating stream, is the fire in the airgiving trunk, in the okolostvolny yard of the airgiving trunk or in the main airgiving developments. In this case for prevention of filling with fire gases of developments of the mine in the majority of work areas, the ventilating stream is reversed due to change of an operating mode of the fan of the main airing (transition from a delivery way of airing to soaking up and vice versa).

As showed calculations, transition process at reversion of an all-miner ventilating stream can last long enough. It is possible to draw the following conclusions:

- the developed spaces of mines and mines influence duration of transition to the reverse or zero mode of ventilation at emergence of accidents, creating aerodynamic transition processes in ventilating networks;

- transition process in branches of ventilating network after reversal of the fan of the main airing can lasts from 20 to 90 min., and the speed of change of pressure will decrease at the same time in proportion to the relation of a difference of pressure between final and current value to pressure relaxation period.

The practical value of work consists that the received scientific results allow to estimate an aero gasdynamic situation at accident and duration of a transition period of emergency ventilation, to choose the most rational emergency operation and to plan the safest escape routes of workers from emergency sites.

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RESULTS OF THE RESEARCH INTO PARAMETERS OF THE DRAINED MATURE TAILINGS BODY DETERMINING THE CHOICE OF MINING TECHNOLOGIES FOR ITS DEVELOPMENT*

In the course of the combined mining [1] of the Sibayskoe deposit, large-scale technology-related waste deposits have been formed. The most environmentally harmful deposits of the kind are tailing storage facilities, which cover vast areas. Mineral processing wastes of the earlier years disposed to these technology-related formations are characterized by high concentrations of valuable components; therefore, the research into the parameters of these assets has been always of great importance [2-7]. Over recent years, in the context of ore reserves depletion at natural copper pyrite deposits under development, the importance of tailing storage site mining has developed into pressing necessity. The analysis of the available and approved approaches to the discharge of tailings generated by the Sibayskaya Processing Plant has shown their low efficiency and non-compliance with the requirements of industrial safety because of the extreme heterogeneity of properties of the man-made technology-related deposit in terms of depth and area [8]

Within the framework of the studies of 2018-2019 the researchers investigated the parameters of the drained body of the Sibaisky GOK mature

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tailings covering the area of nearly 2 km^2 and having irregular thickness ranging from 5 to 20 m. In the course of geological evaluation performed in the summer period pits were dug by an excavator to a depth of 6 m, each of which was sampled with interval of 1m. The results of sampling proved high concentrations of valuable components, and this became a headstart of further exploration of the tailings storage site. Beside, in the course of studies, some consistent patterns were discovered of the variation of main characteristics determining the choice of mining technology – pH and moisture variation with depth. For the enhancement of the informative value and detalization of exploration it was decided to perform sampling in the winter period, as there was an assumption that at lower temperatures the bearing capacity of soil of the tailing storage site surface would be significantly higher, and in its turn could provide an opportunity of drilling equipment movement.

In the winter period, in the process of research into the condition of the surface it was discovered that the tailings body surface bearing capacity had not changed (depth of frost is zero), and operation of mining machinery would be possible only in some limited areas. With the use of Ural URB-2A2 truck-based drilling rig 8 holes were drilled through the total thickness along the perimeter of the Sibayskoe tailings storage site. It was found that high acid condition of the medium - up to pH of 1.5 in the upper part of the thickness to the depth of 1.5 to 3 m could increase the risk of mine machinery corrosion. Besides, in the course of hole drilling some heavily-watered areas were found from a 13 m depth downward. These factors make the operation of heading machinery even more problematic, therefore it requires specific approaches to the selection of mining methods.

For the selection of engineering solutions of tailings storage site development the analysis has been performed, and alternative methods of technology-related man-made deposit development, as well as types of mining and loading process mechanization, and most feasible scenarios of waste transportation have been proposed.

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COMPLEX MONITORING RESULTS OF THE ULTRA DISPERSE AEROSOLS CONTENT IN THE MINING INDUSTRY REGIONS

Modern studies prove that nanoscale structures are not only the main breakthrough in the field of high technologies with the rapid development of nanotechnology, but also one of the causes of environmental pollution [1]. According to the classification presented in [2], ultrafine aerosols, which size is in the range of 0.001–0.01 μm, are nanoparticles. Moreover, some ultra-small inhaled insoluble particles may be more toxic than larger ones of similar composition [3-10]. From these works it is known that a part of such aerosols in nature are formed as a result of natural processes and, being balanced by the general circulation of substances in nature, do not cause profound environmental changes. Part of ultrafine aerosols is formed as a result of human activity, being, in our opinion, the main factors for the deterioration of its habitat. At the same time, currently there is no standard in Russia that establishes maximum permissible concentrations of such nano aerosols in air. In 2012 GOST R 54597-2011 was approved, the purpose of which was to provide users with the necessary background information on nano aerosols before specific maximum allowable exposure levels and standards were developed and implemented [11].

The new technological structure, the development of which is associated, among other things, with the creation of new devices and environmental control methods, provides for a new approach to monitoring working conditions in mining enterprises.

For this purpose, a technique has been developed for the maintenance of ultrafine aerosols in areas of intensive mining of mineral deposits [11].

Due to the lack of reliable data on the maximum allowable concentration of nanoparticles in the atmosphere of mining regions and adjacent urbanization zones, the main indicators characterizing the degree of air pollution by nano aerosols, according to the methodology, can be identified by a comparable assessment.

In the course of research conducted using the DISCmini diffusion classifier of the *ICEMR RAS* laboratory [13], the content of ultra- and highly dispersed aerosols in the atmosphere of the mining industrial regions of KMA (Kursk

Magnetic Anomaly) and the Southern Ural [14,15] was determined. For a "reference" region, urbanized areas characterized by the absence of mining enterprises (Moscow and Dolgoprudny, Moscow Region) were selected for a comparative assessment. According to the measurement results, it was found that the average concentration of ultrafine particles in Moscow is 2.3 times less than the maximum values in the mining regions of the southern Urals and the KMA region. A comparative assessment with the content in the air of ultrafine aerosols in the area of MMK Magnitogorsk showed that the maximum concentration is 121453,485 cm-3, which exceeds the maximum values in the mining industrial regions of the KMA and the Southern Urals, by 4.4 times Moscow, 10 times.

The purpose of the state monitoring of the human environment is not just a statement of its pollution. Similar studies in other mining centers in Russia, as well as the subsequent study of the mechanisms for the formation of nanoparticles, will contribute to the development of innovative technologies for sustainable environmentally balanced development of ore deposits [16-18], which reduce the negative impact of geo technologies on humans.

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PROJECT FINANCING AS THE BASIS FOR COMPLEX USAGE OF NATURAL AND TECHNO GENIC GORESOURCES

The implementation of large-scale projects in the field of subsoil use, especially in modern conditions, requires a search for specific approaches to the search for sources of their financing. One of the modern, but positively proven methods is project financing. This method, based on the organization of attracting investment in the real sector of economy, allowing it to maintain its interaction with the financial and banking sector, provides an opportunity for the participation of an unlimited number of investors at various stages of project implementation. This is especially important in terms of implementing the idea of cumulative use of natural and man-made georesources, which implies using not only mineral reserves, but also man-made structures within the framework of a functioning mining system to be used in the development

of a subsoil plot. At the same time, the purposeful formation of a specific techno genic object determines the need for it both in the short and long terms.

Monitoring the region needs in man-made objects that can be formed in the process of mining, is an integral part of the development efficiency of the subsoil plot. At the same time, the object being created may be an independent business entity not related to the extraction of mineral resources. In particular, therefore, the method of project financing contributes to an increase in the long-term perspective of the competitiveness of economic entities, which determines the growth of the state economy, within which the project is implemented for the cumulative use of natural and techno genic georesources, taking into account possible risks.

Thus, in modern conditions, increasing the efficiency of implementing large-scale subsoil development projects based on the application of project financing methods is particularly relevant, as the use of this mechanism ensures the investment attractiveness of the subsoil sphere use and also contributes to the optimal distribution of project risks inherent in all mining enterprises operating in the zone of high technological and financial danger. Achieving investments and subsequent investment activity contributes to the environmental efficiency of mining production and regional development of the mineral resources exploitation. At the same time, the study of general methods of stimulating project financing contributed to the development of the presented author's methodology, taking into account the individuality of each investment project in the absence of a universal methodology.

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ON THE QUESTION OF WORKERS' LABOR RATING DURING DRIVAGE OF UNDERGROUND MINING WORKINGS

One of the main criteria for the mining enterprise efficiency is the labor productivity growth. Improving the technology of carrying out and mounting mining, the introduction of adaptive means of mechanization and automation of labor in combination with modern methods of regulation of labor activity can significantly improve the labor productivity of this process.

The issues of labor valuation are devoted to a lot of research and accumulated extensive experience in domestic and foreign practice. With sufficient detail the authors studied the features of the calculation of technical and operational performance of drilling, loading and transport machines,

depending on the physical and mechanical properties of the mountain range, the paper identified factors that reduce the performance of equipment and labor in general. However, there is no modern regulatory framework that allows you to ration the main technological operations.

At the moment, the only official documentary that allows to determine the estimated standards of time and production is the Resolution of the Ministry of Labor of the Russian Federation of April 21, 1993 No. 89 “On approval of Integrated time standards for mining and rifled mining works of mines of the mining industry and in geological exploration” (hereinafter "Integrated regulations").

The application area of the norms of time and production is wide enough: from the development of intra-company norms and the plan tasks calculation for the piece-rate wage system to the composition selection of the complex of mechanization and the planning of production indicators in the development of projects.

The method of calculating indicators proposed in the Resolution is convenient and informative, but does not take into account the diversity of mining and geological factors that affect equipment performance.

The calculation of production rates for the tunnel cycle operations in order to assess the feasibility of their adjustment was made on the basis of indicators comparison calculated according to normative documents and actual ones, as well as by analyzing the conditions of research at one of the Ural underground mines.

On the basis of work time study (WTS), the production rates for the main technological operations were calculated.

Three groups of indicators were used for comparison and analysis the calculation of which was carried out according to the method proposed in the collection of Integrated standards:

- the rate of time and the rate of production, calculated according to the data given in the collection of Integrated standards,
- also calculated according to the WTS data without regard to downtime,
- also calculated according to WTS data, but taking into account the downtime.

For all operations subjected to analysis and calculation, excess of indicators of time standards planned over actual ones (excluding downtime) was found: from 3% drilling boreholes when penetrating, up to 275% of face drilling boreholes. The data calculated taking into account downtime and without it are cast several times, which indicates the presence of a large reserve of increased productivity by improving organizational work and reducing downtime. This was indicated in the recommendations of the enterprise.

Considering the mentioned data, the need that becomes obvious is to obtain more complete information about the possible performance of units of equipment in various geological conditions, about the influence of various factors on the equipment performance in order to update the Integrated Standards data.

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SCIENTIFICALLY METHODOLOGICAL AND PRACTICAL ENSURING THE STABILITY OF QUARRIES SIDES, BENCHES, OPEN CUTS AND DUMPS

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PIT SLOPE OPTIMISATION BASED ON RISK ASSESSMENT

Any failure in a pit should be controlled in different large-scale levels – benches, inter-ramp slopes, overall slopes, as this affects the technological process, the economic efficiency of the enterprise and the safety of work.

The risk of slope failure takes place due to uncertainty or high heterogeneity of the initial data, which include geological bodies and structures, geomechanical parameters, hydrogeological conditions, as well as methods and models can have some assumptions.

To take into account the effect of uncertainty or variability of the initial data on stability of designed slopes, the definition of probability is introduced.

The probability of slope failure is determined by multiple safety factor calculation using variable input parameters within their range of values selected by the Monte Carlo method. As a result of this analysis, the probability of slope failure is determined as a ratio of number of simulations with safety factor less than 1 to the entire volume: $PoF = P[FoS \leq 1]$, %.

Management of slope stability is based on a definition of the risk of failure, which depends on the probability of failure and the level of consequences after the slope failure: $R = PoF \times (Consequences)$.

Based on this, it is a way to optimize the slope design through reducing the risk of negative effects after the failure by influencing of either parameter:

- reduction of the probability of failure is achieved by improving the reliability of initial data, detailing the assessed models with involving maximum number of influencing factors (modern software packages allow this), drainage, changing the construction of pit slopes.
- negative consequences after the failure depend on inner infrastructure of pit, location of ramps, work zones and scale of the failures. Its impact is reduced due to technical activities (slope support, monitoring, designing a wide catching berm, reserve ramp, etc.), organizational activities to ensure the safety for personnel and mining equipment while working in potentially dangerous areas, risk management, etc.

Minimizing of failure risks allow to implement more optimistic strategy for optimizing of slope design.

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WAYS OF CONVERGENCE OF RUSSIAN AND FOREIGN METHODS FOR ESTIMATE THE STABILITY OF OPEN PIT SLOPE AND BENCHES

The operation of large-depth quarries, the design and construction of ultra-deep quarries in complex geological engineering and hydrogeological conditions places high demands on the initial data and methods of geomechanical substantiation of the parameters of the open pit slope and benches.

At present first glance, there are large differences between Russian and foreign approaches to assessing the stability of slopes and benches of quarries. At the same time, deep open pit with steep slopes, are being operational not only in Western countries, but also in Russia. For the analysis and comparison of Russian and Western approaches, two of the most basic stages in assessing the stability of slopes and benches were analyzed, (tables are presented in the report): 1. Methods for assessing the strength and deformation properties of a rock mass. 2. Methods for assessing the stability of benches and open pit slopes and cuts.

Despite a number of discrepancies between Russian and Western approaches, the parameters of open pit slopes and benches with fairly close values, can be justified in the rock mass. This is due, firstly, to the fact that in rock mass the overall angle depends on the number of benches, their parameters and benches width. Secondly, the limiting parameters of the open pit slope are most importantly influenced by the structural architecture of the mass (faulting). At the same time, the calculation of the weakening surfaces in calculations is carried out by very similar methods, therefore, the parameters of the slope and benches are very close.

Recently more and more specialists are striving to use both Russian approaches and foreign approaches in their research. Increasingly used foreign software. Therefore, an integrated approach is already being implemented using two different scientific schools. Thus, when creating the Federal rules and regulations of the «Rules ..» in annexes for determining the properties of rock mass (Appendix 8) and performing calculations (Appendix 5), a combined approach will be given. The basis is already taken in the standardized Russian approach, which are complemented by developments in recent years. These approaches are being expanded by methods that have proven themselves in the West (primarily software). Thus, the applications will meet both Russian and foreign standards, but taking into account Russian specifics.

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MODERN METHODS OF GEOMECHANICAL DATA COLLECTION

The technologies of rock mass studies have seen significant progress in the age of modern information technologies. Over the last decades, information technologies have advanced from computers occupying whole rooms or floors of buildings to pocket size devices.

Without doubt, the studies are concerned with the same rock mass and its properties, however the techniques and methods progress towards greater safety, speed of data collection and processing, and ability to collect more statistical data.

Currently geotechnical engineers have the following tools available:

- Mechanical and electronic tools for drill core orientation;
- Tools and software for downhole surveys (acoustic and optical);
- Tools and software for photogrammetric mapping of pit walls (Sirovision, drones);
- Laser scanning for studies of structural features;
- Monitoring tools (radar, optical, laser systems, downhole sensors) working in remote control mode (with no people in hazardous zone) and with automatic data collection;
- Tools for virtual data collection (future developments).

Using all these systems makes the geotechnical data safer and faster to collect and process and allows increasing the amount of data collected. Traditional methods remain to be a mean of verification for the collected data.

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REVISITING THE CHOICE OF STABILITY COEFFICIENT OF SIDES, THEIR PLOTS, HIGHWALL SLOPES AND DUMPS

The main characteristic of assessing the geomechanical stability of high wall slopes, which determines (ensures) safety and efficiency of mining operations, is the stability coefficient (SC), the recommended values of which during mining are determined by regulatory documents requiring revision and updating [1].

Despite the fact that the main factors affecting the value of the stability factor of slopes are well known, the SC values recommended by the current regulatory literature do not have a sufficient degree of detail in terms of the service life of objects, stages of field development, as well as the method of obtaining initial characteristics. The possibility and limits of the application of the analogy method are also not substantiated; the characteristic of the adjacent rock mass of a side section requires a separate consideration - a group of

benches outlined by a common sliding surface, along which the stability (prediction) of the entire group of slopes is assessed, are not considered mines composed of permafrost rock.

This paper is devoted to the elimination of some of these shortcomings. The recommended values of the stability coefficient given in it can be adjusted for specific conditions, recommendations on adjustments are given.

It should be noted that the criteria for assessing the geomechanical stability of the side wall may change along with the development of monitoring technologies and the safety policy of mining companies, which is reflected in the international approach to the assessment of quarry side stability [2].

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CONSIDERING THE SPECIFIC OF COMBINED GEOTECHNOLOGY IN THE FEDERAL RULES AND REGULATIONS IN THE FIELD OF INDUSTRIAL SAFETY "RULES FOR SIDES, BENCHES OF QUARRIES, OF OPEN CASTS AND DUMPS"

The solution to the problem of ensuring the stability of slopes in the design of combined geotechnologies becomes of particular importance due to the need to improve the interaction schemes between open, open- subsurface and subsurface mining in significantly changing geological, mining and environmental conditions [1-3].

In order to ensure the required safety level of mining operations and completeness of subsoil development, the assessment of the stability of pit slopes and opencast mines for the combined development of a field should be carried out taking into account: the need to maintain protected mine workings and other structures for the entire period of deposit development; changes in the strength characteristics of rocks under the influence of undermining of open and subsurface workings; the effects of explosions, weathering; the need for the safety of sections of the pit walls for the period of open- subsurface and / or subsurface mining of reserves beyond the quarry limiting contour.

With a combined geotechnologies, a complex geomechanical system is being formed; therefore, the stress-strain state of the ground must be determined taking into account the combined influence of open and subsurface work.

The developed rules will consider the method of determining the influence zone parameters of underground mining, the magnitudes and nature of the deformation of the ground and the duration of the process of displacement of rocks and the earth's surface. In addition, special attention is paid to consideration of the specifics of natural and climatic conditions, the cryogenicity of the ground, the water content, the seismic impact of explosions, the region's own seismic activity, up to earthquakes; static and dynamic loads of mining equipment; geodynamic zoning of the subsurface site in accordance with the conditions of managing the state of the rock mass during open and combined (open- subsurface) mining.

Technological methods for controlling geomechanical processes that ensure the safe conduct of mining operations during combined geotechnologies are considered. The features of the organization of monitoring the geomechanical state of the ground in combination with technological solutions to justify the safe mining technology are presented.

The implementation of the requirements of the new federal rules and regulations (FRR) will expand the scope of combined geotechnologies; ensure a safe and effective development of the subsoil.

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THE STUDY OF THE STRESS-STRAIN STATE AND STRUCTURE OF THE ROCK MASS TO ENSURE THE STABILITY OF THE SIDES AND LEDGES OF QUARRIES

One of the priorities of the development of the mining complex is to increase the efficiency and safety of mineral extraction. An important role in solving this problem belongs to the geomechanical provision of technology for the development of mineral deposits. The main source of data on the initial and technogenically altered stress-strain state of the rock massif are field measurements of the parameters of the process of displacement of the near-side rock mass.

The main factors determining the formation of the stress-strain state of the rock mass are:

- hierarchically block structure;
- constant mobility;
- secondary structuring;
- concentration of modern geodynamic movements at the boundaries of secondary structural blocks.

Under their influence in the real rock mass, a mosaic, relatively homogeneous in its averaged integral parameters, a stress-strain state is formed. To identify the parameters and patterns of formation of the initial stress-strain state of the rock mass it is necessary:

- to evaluate experimentally the level of modern geodynamic movements and the parameters of the stress-strain state formed by them, changing in time;
- to investigate the degree of heterogeneity of the stress-strain state, due to the secondary structuring of the rock mass under the influence of modern geodynamic movements and the formation of a secondary stress field in the field of influence of mining.

Thus, it is necessary to obtain by instrumental way two basic types of information: parameters of the integral movement of the massif, caused by natural and man-made factors, as well as data on the hierarchically block structure of the mountain massif and its changes over time. These data can be obtained using direct surveying and geodetic methods, as well as indirect geophysical methods. Among the direct methods, it is necessary to point out remote methods, at which direct contact with the object under study does not occur.

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ABOUT PHASING OF GEOLOGICAL-ENGINEERING INVESTIGATIONS OF PHYSICAL AND MECHANICAL ROCKS PROPERTIES FOR GEOMECHANICS CALCULATIONS

One of the problematic issues in the performance of engineering surveys for project documentation for the construction (reconstruction) of coal mines is the lack of regulatory requirements for the composition and scope of surveys for mining facilities (quarry excavation and overburden dumps). This issue will be resolved in the currently developed Federal norms and rules "Rules for ensuring the stability of the faces and benches of quarries, open cuts and dumps" (hereinafter - the "Rules ...").

It is advisable to divide the work carried out by exploration and survey organizations (divisions). The main object of study of the first works is semi-rock and rock rocks, of the second ones is dispersed soils (and the first meters of semi-rock, rock). Accordingly, these types of organizations have different equipment and staffing, and, ultimately, the average cost of work and the time it takes to work is different by an order of magnitude. The only science unites these organizations in terms of geology - engineering geology. Both the first and the second perform engineering and geological research. Exploration

organizations - for the industrial evaluation and development of the field, survey - for the architectural and construction design (mainly - for the selection and calculation of the foundations of buildings and structures).

In addition, specialized in the field of geomechanics organizations perform sampling from the ledges of existing sections, additional laboratory studies (determining the strength properties of rocks by the shear method with compression, determining the strength properties of the rocks contacts).

At each subsequent stage of work (exploration, research, additional research), time and financial expenditures for carrying out engineering and geological research are reduced. If for geological exploration the time of work for about a year is considered acceptable, then at the stage of development of a conclusion on the substantiation of the parameters of stable sides and dumps the average time costs are about a month.

In order to prevent unproductive expenditures (duplication of drilling operations) for obtaining initial data for geomechanical calculations, new works on geological exploration (additional exploration) of coal deposits should include not only traditional studies of the strength properties of rock and semi-rock rocks by uniaxial compression and tension, but also new types and objects of research - determination of deformation properties of rocks, determination of strength properties of rocks by the method of shear with compression ("slanting"), and determination of the strength properties of rocks contacts.

It is reasonable to add definitions of geological survey terms and surveys to the "Rules ..." being developed in accordance with the existing regulatory framework and the practices of the relevant organizations. There is a geological prospecting of mineral deposits, for which the term "engineering-geological surveys of mineral deposits", which is available in the current edition of the "Rules ...", fully fits. Accordingly, the volume of engineering-geological research, which is proposed to be performed as an engineering-geological survey of mineral deposits, should be carried out at the stage of geological exploration (additional exploration) of a geological deposit (site).

In section 3, "Requirements for engineering-geological study and zoning of rock massifs," it is more expedient to use the term "engineering-geological research", rather than surveys, since the current legal framework puts a narrower meaning in the term of exploration. Research includes exploration, survey work and additional work of specialized organizations in the field of geomechanics at the stage of developing a conclusion.

At the stage of engineering and geological surveys of mountain objects (quarry excavation and overburden dumps), if geological exploration is carried out qualitatively in accordance with the "Rules ..." being developed, dispersed soils are explored in the territory of a future quarry excavation. For external dumps, the depth of the wells is limited to dispersed soils with a depth of 1-3 meters in semi-rock soils. After drilling the first wells (in combination with static sounding) over the entire depth of dispersed soils, it is advisable to carry out preliminary geomechanical calculations and, depending on the results,

more accurately determine the scope of interaction of the external blade and base.

In order to enable the use of modern geomechanical survey programs (as well as geological prospecting) should be carried out on separate profiles located in different geomorphological zones (areas of negative landforms, watersheds, slopes, flat areas).

Rational organization of engineering and geological research at all stages of the life cycle of a mining enterprise, ranging from geological exploration to conservation (liquidation) of a mining enterprise, will allow optimally receiving a full package of engineering geological information necessary to use new calculation methods and algorithms in accordance with the developed Federal standards and the rules "Rules for ensuring the stability of the sides and benches of quarries, cuts and dumps".

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RESTRICTIONS ON SEISMIC EFFECTS OF THE EXPLOSION IN THE MARGINAL ZONE OF THE QUARRY IN THE OPEN AND COMBINED DEVELOPMENT OF THE DEPOSIT

While conducting mining operations in the quarry and underground mine in one vertical plane, the following conditions must be observed: the abandonment of the safety target, ensuring the stability of the massif and the sides of the quarry; the use of development systems that exclude the displacement (destruction) of the array of the safety target; the limitation of the power of mass explosions and their seismic effects on the targets, ceilings and ledges of the boards.

With the combined development of the field, the front of mining operations in the quarry is located in the direction towards the front of the development of underground treatment works. At underground treatment works the front develops in the direction from the massif to the quarry [1, 2].

Blasting operations in the quarry should be carried out in such a way that the speed of seismic vibrations of rocks in the area of underground mining does not exceed the maximum permissible values for stability. To determine the permissible value of the seismic velocity, it is necessary to set the permissible dynamic stress in the array. The permissible dynamic tensile strength is in accordance with the condition of seismic resistance of the output:

$$[\sigma_{ст}] + [\sigma_{дин}] \leq \sigma_{дин}$$

где $[\sigma_{ст}]$ – static electricity in the mountains surrounding the production, $[\sigma_{дин}]$ – dynamic voltage in the array, $\sigma_{дин}$ – the permissible dynamic tensile strength of about production.

The values of ultimate strength in stretching for sample and array breeds differ significantly (5 – 10 times and more). It is possible to estimate reliably the value of the static tensile strength of the array only experimentally, which is impossible at the initial stages of design. In some cases, an approximate calculation is possible, taking into account the average coefficient of structural weakening and on the basis of the rock strength passport. In the approximation for the permissible dynamic tensile strength of rocks σдин you can take the static limit of the rock strength tensile σр increased by 10 - 30%.

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