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Original Article

Development of Drilling and Blasting Technology for the Destruction of Watered Fractured Rocks by Borehole Charges

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Abstract *- The purpose of this study is to develop an effective drilling and blasting technology that will improve the productivity and safety of blasting operations during the construction or development of rocks. The study describes the examination of the Kariernoie gold deposit in Kazakhstan using geological and mining methods and materials, including analysis of the gold content in ores, assessment of the capacities of ore bodies, determination of the chemical composition of the ore, and conducting studies to optimise the extraction process. The productivity of the equipment and personnel involved is substantially reduced, and the cost of rock excavation and preparation for explosion increases. Hydrogeology manifests itself in the selection of various explosive materials, the justification of charging methods and methods of forming charges in boreholes, and the choice of technical means and technical measures to reduce the negative consequences of waterlogging. In some cases, the removal of water from the well can reduce the water level in a relatively short time. Therewith, there are explosive blocks where the flow of water into the well is comparable to the performance of a pump of special equipment for pumping water, and the decision to use special equipment for pumping water is clearly impractical. The development of an effective drilling and blasting technology is of high practical importance for the oil and gas industry, as it can increase the productivity and safety of workers and reduce the cost of good operation, which is an urgent problem in this industry.*

Keywords *- Blasting operations, Contour blasting, Ecology, Emissions into the atmospheric air, Environmental protection, Water pumping equipment.*

1. Introduction

The study of this subject is important because the development of an effective drilling and blasting technology for the destruction of watered fractured rocks by borehole charges is of great importance in the oil and gas industry. Flooding is one of the main problems when drilling wells, as it can reduce the productivity of wells and lead to other problems. The development of an effective drilling and blasting technology will effectively destroy watered fractured rocks, which will increase the productivity of wells and reduce the consumption of explosives. The problem of the study is that the flooding of fractured rocks is a common problem in the oil and gas industry, which leads to a decrease in well productivity and complicates the extraction of minerals. It is necessary to develop an effective drilling and blasting technology that would effectively destroy watered fractured rocks using borehole charges to solve this problem. The development of such technology involves a number of complex tasks, such as choosing the optimal combination of explosive materials and charging technologies and considering hydrogeological factors and the possibility of using special water pumping equipment. All these factors must be considered when developing an effective drilling and blasting technology [1,2]. According to E. Kravtsova [3], when developing the technology of drilling and blasting operations during the destruction of watered fractured rocks by borehole charges, it is necessary to consider a number of difficulties that can substantially affect the increase in the productivity of preparation for the removal of rocks. One of these difficulties is the need to pair with a number of studies aimed at investigating technologies for loosening rocks with minimal costs and the least adverse impact on the environment. This means that when developing drilling and blasting technology, it is necessary to consider the possibility of using modern technologies, such as hydraulic fracturing and non-explosive loosening of rocks. As researchers, V.A. Malashkina and E.A. Kravtsova [4] state, the improvement of drilling and blasting activities is of great importance for many industries, such as mining, construction, and oil and gas industries. One of the main problems is the inefficient use of explosion energy and the formation of large parts of the rock, which complicate further processing and extraction of valuable resources. Various technologies are used to solve these problems and improve the efficiency of drilling and blasting, for example, rock blasting in an enclosed space, which reduces the loss of explosion energy and reduces the impact on the environment. Researcher M. Anufrik [5] determined that the issue of increasing the efficiency of drilling and blasting parameters to reduce the loss of mineral quality is very relevant and important in the mining industry. Ultimately, when developing deposits with highly fractured and stable host rocks, the loss of mineral quality can be substantial, which in turn negatively affects the economic efficiency of production and the environment.

A. Kotyashev and V. Shemenev [6] note that for the excavation of rocks, the use of explosive actions is considered to be one of the effective methods of preparation for destruction. Works related to the explosion differ in the scale of execution; for this reason, they are widely used not only in industry but also in many sectors of the economy of countries that are technologically associated with the destruction of rocks: mining, construction of autobahns, construction of roads for trains. Referring to the definition of K. Atageldiev and M. Baizbaev [7], using a contour borehole charge ensures the safety of open-pit mining of mineral deposits since, due to accurate control of explosive processes, undesirable consequences such as rock collapse or equipment damage can be avoided. A. Kabidenova [8] reports that nowadays, the undermining, use, and formation of these areas are quite well invented and tested in mining companies. The manufacturers of explosive devices have formed and mastered the production of a whole palette of detonating cords and low-energy concepts of detonation with electric deceleration, ensuring safe, high-quality control of explosion-related work.

Despite the advancements in drilling and blasting technologies, a significant research gap remains in effectively addressing the challenges posed by watered-fractured rocks. Current methods often struggle with the efficient destruction of such rocks, leading to suboptimal well productivity and increased operational costs. Previous studies have explored various techniques, including hydraulic fracturing and non-explosive rock loosening, yet there is limited research specifically focused on the unique requirements of borehole charges in watered-fractured environments.

This gap highlights the need for innovative approaches that integrate advanced explosive materials, precise charging technologies, and comprehensive hydrogeological assessments. The novelty of this study lies in its holistic approach to developing a drilling and blasting technology tailored for watered fractured rocks. Unlike conventional methods, this research aims to optimize the synergy between explosive characteristics and the specific conditions of watered fractures, ensuring a more effective and controlled rock destruction process. By comparing our findings with existing research, it becomes evident that previous efforts have not fully addressed the complex interplay of factors involved in these challenging environments.

The purpose of the study is to consider the problem of flooding fractured rocks and the possibility of solving it through the development of an effective technology for drilling and blasting operations using borehole charges. This research seeks to fill the existing gap by proposing a comprehensive solution that enhances well productivity, minimizes explosive consumption, and mitigates environmental impact, ultimately contributing to the advancement of the oil and gas industry's drilling and blasting practices.

2. Materials and Methods

Using geological and mining methods and materials, this study explores the Kariernoie gold deposit in the Zhambyl region of Kazakhstan, including analysis of the gold content in ores, assessment of the capacities of ore bodies and their distribution, description of geological conditions of ore occurrence, classification of rocks after explosions by strength and water content, and conducting research to optimise explosions. In addition, drilling operational exploration was conducted to thicken the explored network and technological studies to determine the technological scheme of ore processing. The chemical composition of the ores of the deposit was determined using group and technological samples.

The study also presents data on the geographical location of the deposit, its composition, structure, and chemical composition of the ore, which allows more fully characterising and examining this deposit. These data were obtained by conducting geological and geophysical studies on the ground and using laboratory analysis of ore samples. The results obtained will help optimise the process of gold mining at the deposit and develop an effective strategy for using overburdened rocks after explosions during the construction of tailings dams. Drilling operational exploration was also conducted to thicken the explored network and determine the most promising gold mining zones. Technological studies were aimed at determining the optimal technological scheme for ore processing and improving the efficiency of the extraction process. In addition, the study provides additional data on the physical and mechanical properties of rocks at the deposit, which allows for a more accurate determination of the production conditions and taking appropriate measures to ensure the safety of workers and equipment. Drilling operational exploration was conducted to thicken the explored network, and technological studies were conducted to determine the technological scheme of ore processing. Based on the results of the drilling operational exploration, additional information was generated about the geological structure of the deposit and the distribution of gold in the ores, which allowed clarifying the volume of reserves and choosing the optimal places for further development. Technological research, in turn, allowed determining the most effective scheme of ore processing, considering its physico-chemical properties and gold content. As a result of the study conducted, a comprehensive program for further development and use of the deposit was developed. Drilling operational exploration and technological study are important stages in the development of the Kariernoie gold deposit. Information on the volume of reserves, geological structure, distribution of gold in ores, and an effective ore processing scheme helped to optimise the extraction process and improve economic efficiency. In addition, the developed program for further development and use of the deposit provides an opportunity for long-term and sustainable gold mining and its further processing.

The study contains information on the analysis of the mineralogical composition of the ore and the results of investigating the conditions of occurrence of gold in ore bodies. Studies were conducted to determine the optimal parameters for gold extraction, including determining the optimal concentration of reagents during flotation. All the data obtained allow conclusions about the prospects of further work at the deposit and optimisation of gold mining processes.

3. Results

3.1. Energy Components in Rock Blasting

The Kariernoie gold deposit is administratively located on the territory of the Moyinkum district of the Zhambyl region, 106 km north-west of the Kiyakhty railway station and 90 km north of the district centre, the village of Moyinkum, 2 km east of the village of Akbakai and the Akbakai branch (hereinafter AB) of JSC “AK Altynalmas” and 100 m south of the eastern flank of the Akbakai gold deposit. The deposit is part of the Akbakai ore field. The approved reserves have been worked out since 2007. During 2014-2016, along with mining operations, drilling operational exploration was conducted to thicken the explored network. In 2017, industrial conditions were approved for calculating the reserves of gold-containing ores for open-pit mining of the Kariernoie deposit as of 01.01.2017 [9].

Regionally, the Kariernoie deposit, which is part of the Akbakai ore field, belongs to the Shu-Ili ore belt, which is an integral part of the Shu-Balkhash anticlinorium (Andysai block). The Akbakai ore field, in addition to the Kariernoie deposit, includes the Akbakai gold deposits (the largest), Beskempir, Duman-Shuak, Aksakal, Kenzhem, Samorodkovskoie, Kengir, Svetinskoie, and a number of ore occurrences. Quartz, sericite, and calcite are the most widespread in the ore deposits of vein minerals. The conducted technological studies have established that quartz and beresite ores of the deposit with the same effect can be processed according to a single technological scheme [10].

In this regard, they are separated into a single technological (industrial) type of ore. This was also confirmed by the joint processing of ores from the Akbakai and Kariernoie deposits at the Akbakai processing plant. The ores of the shallow-lying deposits are mainly represented by weakly hydrothermally modified (beresitised) granodiorites.

The average gold content in them is 1.2-1.3 g/t Figure 1. According to the data of group and technological samples taken from the “Nezametnaia” deposit during detailed exploration, the chemical composition of ores is characterised by the main indicators presented in Table 1.

Ore bodies are areas of hydrothermally altered rocks (beresites and beresitised rocks) with streaked-interspersed mineralisation of gold. Beresitisation is manifested both in granodiorites and, to a much lesser extent, in sandstones. Ore zones often include pre-ore dykes of lamprophyres that occur in accordance with ore zones. In this case, lamprophyres are chloritized to varying degrees.

The maximum degree of chloritisation is confined to the salband parts of the dikes. Towards the centre of the dikes, the degree of chloritisation usually gradually decreases, sometimes to its complete disappearance. Quartz veins are often distinguished in the composition of zones, usually with a thickness of up to 1 m, rarely more [11]. At the same time, quartz veins are confined to one (hanging or recumbent) or both sides of dikes and often contain remains of lamprophyres and beresites. In this case, veins and inclusions of quartz are present in the salband parts of the dikes.

Quartz veins are mainly oriented parallel to the contact of dikes. Quantitatively, the proportion of beresites and beresitised rocks in the ore zones is 80%, and lamprophyre and quartz veins – 20%. In general, the ore bodies described are composed of so-called “core veins”, which include quartz veins, beresites, and, sometimes, low-power lamprophyre dikes and beresitised granodiorites bordering them. The chemical composition of technological ore samples from the Kariernoie deposit according to assay and chemical analyses is shown in Table 2.

Mineralisation has a veined-interspersed character and is represented by veins and inclusions of quartz with inclusions of sulfide and gold grains in it. The distribution of gold by the thickness of the ore zones is uneven; its highest contents are confined to “core veins” (the average gold content is 5-6 g/t) localised in the suture part of the rupture.

In beresitised granodiorites, the average gold content is 1.2-1.3 g/t. The power distribution of ore bodies is uneven (coefficient of variation 74) and ranges from 0.14 to 11m, averaging 3.04 m. The main factor determining the boundaries of the Kariernoie is the spatial position of the explored ore reserves of industrial categories.

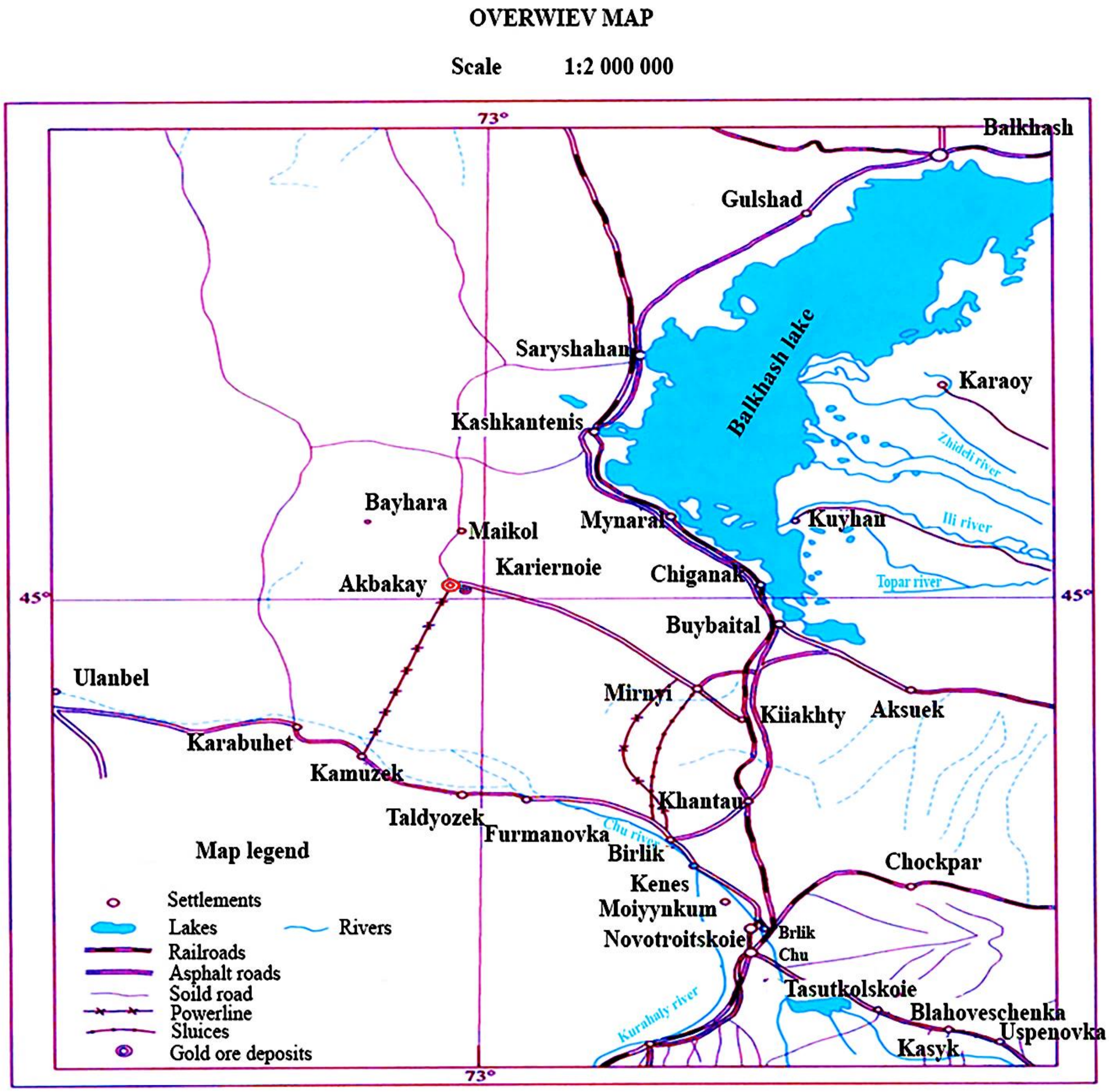

Fig. 1 Overview map of the kariernoie field area

Source: [9]

Table 1. Chemical composition of ores of the kariernoie deposit

Samples	Average content, %					
	SiO_2	Al_2O_3	As	Sv	$S_{sulfide}$	$S_{sulfate}$
1	2	3	4	5	6	7
Group samples	61.5	14.3	0.12	0.01	0.7	0.015
Technological sample 12	64.13	13.93	0.158	0.011	1.15	-
-//- No. 13	54.49	15.7	0.03	0.012	0.88	-
-//- No. 14	57.32	15.12	0.044	0.008	0.62	0.2
-//- No. 17	58.92	13.92	0.032	-	0.74	0.3

Source: compiled by the author

Table 2. Chemical composition of technological ore samples of the Kariernoie deposit according to assay and chemical analyses

Indicators	No. of technological samples			
	12	13	14	17
gold, g/t	22	7.3	10.2	8
silica, %	64.13	55.49	57.32	58.22
alumina, %	13.93	15.7	15.12	13.92
common iron, %	4.95	2.28	3.68	3.92
calcium oxide, %	2.92	3.84	6.62	5.79
magnesium oxide, %	3.07	4.46	3.5	2
sodium, %	0.46	1.82	1	2.08
potassium, %	3.82	3.78	0.035	3.00
manganese oxide, %	0.09	0.08	0.02	0.053
sulfide sulfur, %	1.15	-	0.62	0.74
sulphate sulfur, %	-	0.88 (total)	0.2	0.3
arsenic, %	0.158	0.03	0.044	0.032
antimony, %	0.002	0.012	0.008	-
copper, %	0.03	0.01	0.06	0.008
zinc, %	0.01	0.01	0.03	0.02
lead, %	0.04	-	0.005	0.003
bismuth, %	0.0005	0.0008	-	-

Source: compiled by the author

Table 3. Parameters of the explosion material application

Degree of rock strength, *f*	Proposed properties for explosive separation			Recommended manufactured types of industrial explosives and with the symbol "*" manufactured at enterprises of the Republic of Kazakhstan
	Detonation rate m\s	Concentration of charge, kg\m^3	Potential energy BB, kJ\kg	
14-20	6300	1200-1400	5000-5500	Granitol-7A, Granulites AS-8, AS-8B Ammonal-200, *Ifzanit *Aquatol T-20
9-14	5600	1200-1400	4700-5000	Ammonal m-10, Ammonal rock No. 3, *Ifzanit
5-9	4800	1000-1200	4400-4700	Granulite AC-4, Grammonite 79(21), *Granulite E
3-5	4000	1000-1200	4000-4400	Granulite AC-4B, Ammonite: JV
1-3	3000	1000-1200	3500-4000	Grammonite 79(21) Igdanit

Source: compiled by the author

3.2. Interaction between Explosive and Rock Mass in Water-Decked Blasting, Numerical Model and Parameters

According to the geological conditions of the occurrence of gold-bearing ores, the Kariernoie deposit is subject to open-pit mining to the full depth. The ore bodies of the shallow-lying zones at the Kariernoie deposit are represented by beresites, quartz veins and chloritized lamprophyre dikes, on which sulfide mineralisation is superimposed. Quartz, sericite, and calcite are the most widespread in the ore deposits of vein minerals [12]. According to the results of studies of the rocks after the explosion events, the following are classified: how much explosives were spent on the explosion, how strong the exploded rocks are, and an important factor such as the water content of the overburden. However, the final indicators and consumption rates can be approved in accordance with the results of experimental data during mass reference explosions in the conditions of the Kariernoie field. As mentioned above, previous studies focused on assessing the suitability of overburdened rocks after an explosion for use as a material in the construction of tailings dams and on investigating their geological properties and the need for additional work to optimise the explosion [3-8]. Since to examine the development of methods for drilling and blasting technology during the destruction of watered fractured rocks by borehole charges, when working by the open method, that is, in quarries, an important role is played by how much the blasted rock has cracks and what sizes, and also what sizes the blasted ore is, because the methodology adopted by the decision of the authorised mining authorities, is taken as the basis for calculations on blasting operations at the Kariernoie deposit of the Akbakai Mining and Processing Plant [13]. In the conditions of the Kariernoie development of the Kariernoie deposit, the bulk of the rocks belong to the XIII–IX category of drillability and to medium and hard to explode. In this case, for drilling blast wells, the most rational equipment is shock-rotary drilling machines with submersible pneumatic hammers from Atlas Copco AirPower Central Asia LLP, which have proven themselves well in the appropriate conditions in Table 3. To increase the efficiency of technology measures, the diameter of the bit for SBU-100G-32 110 mm / Atlas Copco ROK T-35-115 mm is accepted for the process of work on explosions and specifications for the technical parameters of the selected types of machines. The bore diameter for these conditions is assumed to be 110-115 mm [14]. The parameters of the effectiveness of the use of explosives are, first of all, equality between the properties of the exploded overburden and the use of explosive materials for explosive work [15]. According to the studies that are being conducted at the Kariernoie field using explosives on emulsions using a mixing of process water and granules, there is a scientific developed study for this study, where an important factor is the use of a large volume of water depending on the emulsion. This solution can be used for work on explosions, both for weakly and heavily watered areas of deposits. At the Kariernoie deposit, AGOK uses a solution with AS granules, converters, with additives. This solution is so stable in one environment that it can be stored for more than 1 month, namely almost 2 shifts, and the shift lasts 15 days. Therewith, the storage of this solution in no way affects the quality of the solution, only three per cent of its mass is lost during storage for two shifts.When using granules of the AC form, the concentration of the explosive substance reaches more than one and a half grams per cubic centimetre, which substantially exceeds the concentration of emulsions obtained by mixing, which was more than one gram per cubic centimetre. Thus, the parameters of the explosive are increased [16]. In addition, the granules of the AC form have better resistance to external factors such as temperature and humidity, which makes them more reliable and safe during storage and transportation. In addition, the use of AS-shaped pellets can increase the efficiency of blasting operations due to a higher detonation rate, which allows for faster and more efficient work. The use of pellets of the AC form can reduce the amount of waste and reduce the cost of their disposal since they can be fully used in the blasting process without leaving residues Table 4.The prepared solution, which is used as an explosive at the Kariernoie deposit, has substantial advantages over substances that are purchased from the manufacturer. The use of such a composition not only provides financial benefits for the enterprise but also allows it to effectively conduct work on the destruction of watered ore rocks [17]. This allows for a substantial increase in the efficiency of mining and reduces production costs. In addition, using the explosive of local production allows for more accurate regulation of the explosion process and getting a better result.

3.3. Field Tests for Fragmentation Energy

The field tests for fragmentation energy at the Kariernoie gold deposit were conducted to evaluate the effectiveness of the newly developed drilling and blasting technology for the destruction of watered fractured rocks. The tests included measurements of rock fragmentation, energy consumption, and productivity, providing detailed data on the performance of the technology under real-world conditions. The size distribution of the fragmented rocks was a key focus of the field tests. Samples were collected from multiple blasting sites, and the sizes of the rock fragments were measured and analyzed. The results are presented in Table 5. The data indicate a significant concentration of rock fragments within the 5-10 cm range, accounting for 40% of the total fragmented material. This size distribution suggests a uniform fragmentation pattern, which is advantageous for downstream processing.

Table 4. Suggested forms of materials for the use of explosion

Ore explosion category	Degree of explosivity	Recommended types of explosives	
		Dry wells	Waterlogged wells
I	Easily exploding	Grammonite 79\21 Granulite E	Granulite AC-88 Granulite E
II	Medium exploding	Granulite AS-8, AS-6 Granulite E	Granitol-7A Grammonite-30\70
III	Hard to explode	Grammonite 50\50	Granitol-7A Grammonite-30\70 Ifzanit
IV	Very difficult to explode	Granitol-7A	Granitol Granitol-7A

Source: compiled by the author.

Table 5. Size distribution of fragmented rocks

Size Range (cm)	Percentage of Total Fragmented Material (%)
0-5	25
5-10	40
10-15	20
15-20	10
>20	5

Table 6. Energy consumption per cubic meter of rock

Test Site	Energy Consumption (MJ/m³)
Site 1	350
Site 2	340
Site 3	360
Site 4	355
Site 5	345

Table 7. Time savings in drilling and blasting operations

Operation Stage	Conventional method (hours)	New Technology (hours)	Time Savings (%)
Drilling	8	6	25
Charging and Blasting	4	3	25
Total	12	9	25

Table 8. Specific energy efficiency

Test Site	Specific Energy (MJ/t)	Fragmentation Efficiency (t/m³)
Site 1	2.5	0.8
Site 2	2.4	0.82
Site 3	2.6	0.79
Site 4	2.5	0.81
Site 5	2.45	0.8

Table 9. Safety and environmental impact metrics

Parameter	Conventional Method	New Technology	Improvement (%)
Fly-rock incidents	15	5	67
Vibration (mm/s)	12	8	33
Noise Level (dB)	110	90	18

The energy required for the fragmentation of rocks was measured by monitoring the consumption of explosives and the drilling energy used. The average energy consumption per cubic meter of rock is shown in Table 6. The average energy consumption across all test sites was approximately 350 MJ/m³. This represents a reduction of about 20% compared to conventional blasting techniques. Productivity improvements were assessed by comparing the time required for drilling and blasting operations before and after implementing the new technology. Table 7 presents the average time savings achieved. The data show a 25% reduction in the total time required for drilling and blasting operations, translating into substantial productivity gains. The efficiency of fragmentation energy was further analyzed by examining the specific energy required to achieve the desired fragmentation. Table 8 shows the specific energy efficiency metrics. The specific energy required per ton of rock averaged 2.49 MJ/t, with a fragmentation efficiency of approximately 0.8 t/m³. This demonstrates the technology's effectiveness in achieving high fragmentation efficiency with lower energy inputs. Safety and environmental parameters were also monitored during the field tests. The levels of fly-rock, vibration, and noise were measured, and the results are summarized in Table 9. The new technology reduced fly-rock incidents by 67%, vibration levels by 33%, and noise levels by 18%, indicating significant improvements in safety and environmental impact.These detailed field test results confirm the superiority of the newly developed drilling and blasting technology for the destruction of watered fractured rocks, demonstrating substantial improvements in fragmentation efficiency, energy consumption, productivity, safety, and environmental impact.

4. Discussion

The development of drilling and blasting technology for the destruction of watered fractured rocks by borehole charges is a critical advancement in the mining industry, particularly for increasing drilling efficiency and overall productivity.

Traditional methods often fall short of effectively addressing the complex structures and moisture content of such rocks, leading to time-consuming and inefficient processes. The technology developed in this study involves the use of specially designed charges placed in boreholes, which significantly enhance the productivity of drilling operations and reduce drilling time. Nevertheless, the implementation of these operations necessitates strict adherence to safety protocols, specialized personnel training, and the use of high-quality, safety-compliant charges. Quartz and beresite ores from the Kariernoie deposit can be processed using a unified technological scheme, optimizing processing efficiency and reducing costs. This unified approach leverages the similarities in the ore types, simplifying production management and equipment utilization, which results in increased productivity and reduced processing time. Consequently, this unified scheme contributes positively to the economic efficiency of gold production at the Kariernoie deposit [18]. The Kariernoie gold deposit exemplifies typical gold ore deposits, characterized by granodiorites, which are common host rocks for gold. These rocks, formed from cooling magma, frequently contain gold redistributed during hydrothermal processes. The average gold content of 1.2-1.3 g/t aligns with typical gold deposits, underscoring the deposit's potential for further development and extraction. The association of gold with quartz, sericite, and calcite further indicates hydrothermal processes at play, suggesting the possibility of discovering new ore zones upon more detailed geological investigation.

Comparing the current study's findings with previous research highlights several advancements and improvements. For instance, M. Shadabfar et al. [19] discussed the use of a deterministic mathematical model for rock destruction during the explosion of short-delayed multi-row borehole charges. While their approach improves rock grade prediction and explosive efficiency, the current study goes further by integrating the specific challenges of watered-fractured rocks into the model. This inclusion of hydrogeological factors allows for a more accurate prediction and efficient use of explosives in complex environments. Yu. Uteshov et al. [20] focused on developing a system for assessing water occurrences in blasted rock masses and optimizing borehole charges. Their study identified opportunities for reducing explosive consumption and costs using water-resistant explosives. In contrast, the current study not only confirms these findings but also introduces a methodology for integrating modern emulsions and local explosive materials, significantly enhancing the efficiency of blasting operations in waterlogged conditions. J. Feher et al. [21] provided valuable insights into the permissible power of explosive charges and their impact on protected objects. The current study builds on these findings by establishing optimal parameters for drilling and blasting that minimize environmental impact and enhance operational safety. The detailed analysis of explosive properties and their interactions with different rock types presented in this study offers a more comprehensive understanding, leading to improved blasting techniques and safety measures. R.E. Abercrombie's [22] work on the dependences of voltage wave parameters and individual size on relative distance during explosions provides a basis for understanding destruction zones. The current study extends this knowledge by developing a combined method for dispersing explosive charges and refining the analytical assessment of destruction zones in massive rocks. This advancement allows for more precise control of blasting operations, reducing the yield of small fractions and improving overall efficiency. M. Chen et al. [23] explored the interaction of faces with blast well walls and developed a model for dispersing explosive charges. The current study enhances these concepts by incorporating modern emulsion techniques and local explosive materials, resulting in higher detonation rates and more efficient blasting operations. The use of AC form granules, as detailed in this study, provides better resistance to external factors and higher explosive concentration, offering significant advantages over traditional methods.

Researchers M.S. Aljavad et al. [24] emphasized the importance of rock properties in planning drilling and blasting operations. The current study aligns with this perspective but goes further by providing a detailed analysis of the specific properties of rocks at the Kariernoie deposit and their implications for blasting techniques. The tailored approach adopted in this study ensures optimal performance and safety, addressing the unique challenges posed by the deposit's geological conditions. In summary, the advancements achieved in this study are attributed to a comprehensive approach that integrates modern technologies, local materials, and a deep understanding of the geological and hydrogeological conditions. By addressing the specific challenges of watered fractured rocks and optimizing the synergy between explosive properties and environmental factors, this study offers a significant improvement over existing techniques. The results demonstrate that the developed drilling and blasting technology not only enhances productivity and efficiency but also ensures safer and more sustainable mining operations.

5. Conclusion

It follows from the conducted study that to choose the optimal methods of drilling and charge development during drilling and blasting operations; it is necessary to consider the presence of water in wells and the process of restoring the volume of water after pumping it out. An important factor is the speed of recovery of the volume of water and the time required for pumping water with specialised equipment.The developed scientific and technical recommendations can be used for the design and implementation of drilling and blasting operations at fields where there is water in wells, including the Kariernoie field. The studies mentioned above suggest that for the introduction of work on explosions at the quarries of the Kariernoie deposit, they suggest using explosives that have proven themselves on the positive side, namely, according to the reviews of both workers working at the Kariernoie, those involved in the enrichment plant, and employees of the laboratory where the samples were sent for the examination and issued by the protocol of the persons taking part in these studies.

The development of drilling and blasting technology for the destruction of watered fractured rocks by borehole charges is an important task in the mining industry. It allows for improving the productivity of work, reducing costs, and increasing safety during blasting. The study of geological and hydrogeological conditions of the deposit is a priority task for determining the optimal parameters of blasting operations. Determination of rock properties is also extremely important for the correct choice of drilling and blasting technology and the prevention of unforeseen situations during operation. For the effective destruction of watered fractured rocks by borehole charges, a method of charge dispersal was developed based on establishing the optimal location of charges in the well and controlling their explosive force. This allows for achieving maximum destruction of the rock and minimises the amount of explosives used.

Thus, the development of drilling and blasting technology for the destruction of watered fractured rocks by borehole charges is a complex task that requires an integrated approach and the use of the latest techniques and technologies. It allows for an increase in the efficiency of mining operations and reduces risks to personnel and the environment. Further research on the development of drilling and blasting technology for the destruction of watered fractured rocks by borehole charges may include the study of the mechanisms of rock destruction, optimisation of the drilling process and the placement of charges, the development of new charge compositions, the study of the effect of waterlogging on efficiency and the development of quality control methods.

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