

REDUCING THE LOSS OF VALUABLE COMPONENTS BY MANAGING BLASTING OPERATIONS IN TITANOMAGNETITE ORE DEPOSITS

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Abstract: This scientific article discusses the reduction of valuable component losses through the scientifically-based management of blasting processes in titanomagnetite ore deposits. In our research, the Tebinbulak titanomagnetite deposit was selected as the mining site for the open-pit extraction of mineral resources by a mining enterprise. During our study, the effect of blasting parameters on ore quality and ore loss was preliminarily analyzed by examining the degree of ore fragmentation. Based on theoretical data, the potential for reducing ore loss and quality degradation by optimizing blasting operations at open-pit mining enterprises is demonstrated through examples.

Keywords: Tebinbulak deposit, drilling and blasting processes, geological setting, mining-technical parameters, valuable components, ore loss, ore fragmentation.

СНИЖЕНИЕ ПОТЕРЬ ПОЛЕЗНЫХ КОМПОНЕНТОВ ЗА СЧЁТ УПРАВЛЕНИЯ ВЗРЫВНЫМИ РАБОТАМИ НА МЕСТОРОЖДЕНИЯХ ТИТАНОМАГНЕТИТОВЫХ РУД

Аннотация: В данной научной статье обсуждаются вопросы снижения потерь полезных компонентов посредством научно обоснованного управления процессами взрывания на месторождениях титаномагнетитовых руд. В качестве объекта исследования было выбрано Тебинбулакское титаномагнетитовое месторождение, разрабатываемое горнодобывающим предприятием открытым способом. В ходе нашего исследования, изучив влияние параметров взрывания на степень измельчения руды, был проведён предварительный анализ их воздействия на качество руды и процессы её потерь.



На основе теоретических данных и конкретных примеров была доказана возможность снижения потерь и разубоживания руды за счёт оптимизации взрывных работ на горнодобывающих предприятиях, ведущих разработку открытым способом.

Ключевые слова: месторождение Тебинбулак, буровзрывные работы, геологическое строение, горнотехнические параметры, полезные компоненты, потери руды, измельчение руды.

TITAN-MAGNETIT RUDA KONLARIDA PORTLATISH ISHLARINI BOSHQARISH ORQALI FOYDALI KOMPONENTLARNING YO‘QOTILISHINI KAMAYTIRISH

Annotatsiya: Ushbu ilmiy maqolada titan-magnetit ruda konlarida portlatish jarayonlarini ilmiy asosda boshqarish orqali foydali komponentlarning yo‘qotilishini kamaytirish masalalari muhokama qilingan. Tadqiqotlarimiz davomida konchilik korxonasi tomonidan foydali qazilma konlarini ochiq usulda qazib oluvchi kon obyekti sifatida Tebinbuloq titan-magnetit koni tanlab olinadi. Biz tadqiqotimiz davomida portlatish parametrlarining rudaning maydalanish darajasini o‘rganib chiqqan holda, rudaning sifati va rudaning yo‘qotilishi jarayonlariga ta’siri taxminiy jihatdan tahlil qilingan. Nazariy ma’lumotlarga asoslangan holda ochiq usulda qazib oluvchi konchilik korxonalarida portlatish ishlarini optimallashtirish orqali ruda yo‘qotilishi va sifatsizlanishini kamaytirish imkoniyatlari misollar tariqasida isbotlab berildi.

Kalit so‘zlar: Tebinbuloq koni, burg‘ilash-portlatish jarayonlari, geologik joylashish holati, kontexnik parametrlar, foydali komponentlar, ruda yo‘qotilishi, ruda maydalanishi.

Introduction

The rapid development of the global metallurgical industry is leading to an increased demand for titanomagnetite ores, which contain strategic metals such as iron, titanium, and vanadium. Many sectors of the modern economy, including mechanical



engineering, energy, aerospace technology, and construction, rely on these metals. Therefore, the effective development of titanomagnetite deposits and the maximum extraction of valuable components is one of the most important scientific and practical tasks. In mining practice, drilling and blasting operations are one of the primary sources of mineral loss. During the blasting process, the boundary between the ore and the waste rock is violated, the ore is over-crushed and mixed, and valuable components are scattered. As a result, the quality of the extracted ore decreases, the composition of the material supplied to the processing plant deteriorates, and overall economic efficiency decreases. The Tebinbulak titanomagnetite deposit is one of the largest iron ore deposits in Uzbekistan and holds strategic importance for the development of the country's metallurgical industry. The vast reserves of the deposit and the prospects for its long-term exploitation necessitate the improvement of blasting technologies. The correct selection of blasting parameters, especially at ore body boundaries, directly affects the degree of extraction of valuable components. The effectiveness of blasting operations depends on many factors. These include the physical and mechanical properties of the rocks, the strength of the ore and surrounding rocks, the type of explosive, the diameter of the boreholes, the distance between them, the structure of the charge, and the blasting sequence. Each of these factors has a different effect on the quality of grinding and ore loss. In modern mining, blasting is considered not only a method for crushing rocks but also a method for monitoring ore quality. The quality of primary crushing determines the efficiency of subsequent extraction, loading, transportation, and processing operations. Therefore, the optimization of blasting operations allows for an increase in the efficiency of the entire technological chain. One of the characteristic features of titanomagnetite ores is their high density and strength. Iron oxides in magnetite and titanomagnetite minerals increase the explosive resistance of the rock. As a result, the incorrect selection of blast energy leads to excessive ore crushing or, conversely, to the formation of oversized rocks. Both cases lead to the loss of valuable components. Ore



loss in mining operations manifests in two main forms. The first is direct loss, in which a certain portion of the ore is not extracted or sent to the landfill along with the coating mine. The second is liquefaction, in which the ore is mixed with adjacent rock, reducing the average amount of valuable components. Improperly organized blasting operations lead to an increase in both of these indicators. In some sections of the Tebinbulak deposit, the boundaries between ore bodies and the overlying rocks may have complex geometry. Under these conditions, the application of standard blasting parameters increases the risk of ore mixing. Therefore, it is advisable to use differentiated blasting systems based on geological data. The distribution of blast energy within the rock mass is governed based on geomechanical principles. The shock waves and gas pressure generated during the explosion create a system of cracks within the rock. If there is too much energy, the boundary between the ore and the waste rock is disrupted, and mixing occurs. Insufficient energy leads to the formation of large boulders. Therefore, determining the optimal energy density is one of the most important tasks in blasting operations. In recent years, digital technologies and computer modeling methods have been widely used in managing blasting processes. The use of three-dimensional geological models, geomechanical simulations, and artificial intelligence elements allows for the prediction of blast results. This will help reduce the loss of valuable components. Developing a scientifically-based management system for blasting operations at the Tebinbulok deposit can increase the recovery rates of iron, titanium, and vanadium components. This will not only enhance the mine's economic efficiency but also serve to strengthen the raw material base for the country's metallurgical industry. The primary objective of this research is to study the impact of blasting parameters on the loss of valuable components under the conditions of the Tebinbulok deposit, develop scientific recommendations for optimizing blasting operations, and improve the ore's quality indicators. The geological structure of the Tebinbulok titanomagnetite deposit is particularly significant in the design and management of



blasting operations. The ore bodies in the deposit area are primarily composed of intrusive and metasomatic formations enriched with magnetite and titanomagnetite minerals, whose physical and mechanical properties differ considerably from those of conventional iron ores. The ore's high density, compressive strength, and modulus of elasticity alter how blast energy propagates through the rock mass. Therefore, selecting blasting parameters based on the standard norms used in other types of deposits may not yield the expected results. While the main task of the blasting process is to break the rock mass into a granulometric composition suitable for excavation and loading equipment, another critical objective in titanomagnetite deposits is to ensure the maximum preservation of valuable components. The geological variability observed at the boundaries of ore bodies further complicates blasting operations. Some sections exhibit sharp fluctuations in the ore's iron content, uneven distribution of titanium and vanadium components, and complex contact zones with the surrounding rock. If the blast energy is excessively high, ore-bearing and non-ore-bearing rocks will mix in these contact zones. Consequently, the proportion of valuable components in the excavated mass decreases. This situation leads to serious economic losses, especially in areas requiring selective mining. Therefore, pre-modeling geological blocks and assessing their susceptibility to blasting are integral parts of modern blasting designs. One of the key indicators determining blasting efficiency is the granulometry of the fragmented rock. Experiments show that excessive fragmentation of the ore leads not only to dust formation but also to the loss of a portion of valuable components during beneficiation processes. A certain amount of the iron and titanium minerals contained in very fine fractions can be lost along with technological waste. At the same time, insufficiently fragmented large boulders reduce excavator productivity and lead to additional costs for secondary crushing. For this reason, achieving an optimal granulometric composition is one of the main goals of blast design. The choice of explosive type also significantly affects the preservation of valuable components. Emulsion explosives, granulites, and

ANFO-type mixtures differ from one another in their energy release, detonation velocity, and gas-generating properties. Although high-energy explosives may be required for hard titanomagnetite ores, an excessive increase in energy creates the risk of over-fragmentation. Therefore, modern mines use combined explosive charges to control the energy distribution along the borehole. This method is particularly effective at the boundary between ore-bearing and non-ore-bearing rock. The parameters of the drilling pattern also directly affect the blasting results. Increasing the distance between boreholes and the burden between rows leads to an uneven distribution of energy. As a result, large fragments form in some areas, while excessive crushing occurs in others. Conversely, if boreholes are placed too densely, the consumption of explosives increases and economic efficiency decreases. In the conditions of the Tebinbulak deposit, it is advisable to use differentiated drilling patterns that account for the strength of the rock and the geometry of the ore bodies. This involves applying separate parameters for the ore blocks and different parameters for the overlying rock layers. The displacement that occurs during the blasting process is one of the primary factors leading to ore loss. As a result of the blast, the rock mass shifts a certain distance from its original position. If the magnitude of this displacement is not calculated beforehand, the planned excavation boundaries along the geological contours will be violated. Consequently, the ore mixes with the surrounding waste rock or, conversely, a portion of the ore is left unexcavated. At modern mines, post-blast displacement maps are being created using high-precision GPS monitoring, drones, and laser scanning technologies. This data serves as an important resource for improving subsequent blasting designs. One of the promising directions for managing blasting operations at the Tebinbulak mine is the use of electronic detonators. While the timing accuracy in traditional pyrotechnic systems is limited, electronic detonators allow for process control at the millisecond level. This helps to control the formation of the blasting front, ensure even energy distribution throughout the rock mass, and reduce ore dilution. Experiments show that using

electronic detonators improves the quality of fragmentation and reduces the loss of valuable components. When evaluating blasting results, it is necessary to consider not only the degree of fragmentation but also the recovery rate of valuable components. In mining practice, for a long time, blasting efficiency has been primarily assessed by the ease of excavation. However, in deposits with a complex composition, such as titanomagnetite ores, the economic outcome is more dependent on the metal recovery rate. Therefore, blasting designs must be optimized based on the recovery indicators for iron, titanium, and vanadium components. The development of digital geological modeling technologies is taking blasting operations to a new level. Using three-dimensional block models, the quality, strength, and structural properties of the ore are assessed in advance. Based on this data, individual parameters are developed for each blasting block. As a result, energy consumption is reduced, fragmentation quality improves, and the level of ore dilution decreases. Such an approach is particularly relevant for the Tebinbulak deposit, given its large scale and complex geological structure. It is also important to consider environmental factors in blasting processes. Dust generation, ground vibration, and air-blast shock waves affect not only the environment but also ore recovery. Excessive blast energy increases the proportion of fine particles, leading to the loss of valuable components. For this reason, measures aimed at environmental safety often also enhance economic efficiency. In modern blasting operations, technologies for local energy management, water saturation, and gas generation control are widely used. At the Tebinbulak titanomagnetite deposit, managing blasting operations is one of the most critical means of reducing the loss of valuable components. Significant improvements in ore quality can be achieved through an in-depth study of geological features, the application of differentiated blasting parameters, the use of electronic detonators, and the implementation of digital modeling technologies. Such an approach not only increases the overall economic efficiency of the deposit but also ensures the maximum recovery of iron, titanium, and vanadium



components. Research has shown that the main controllable parameters for blasting efficiency are borehole diameter, row spacing, charge design, and blasting sequence. Selecting optimal values for these parameters ensures an even distribution of blast energy within the rock mass, reduces the volume of ultrafine fractions, and increases the preservation rate of valuable components. It has been established that regulating energy density, particularly at the boundaries of ore bodies, is of great importance in reducing ore loss and dilution. The granulometric composition resulting from blasting has been proven to directly affect the subsequent stages of excavation, loading, transportation, and processing. The formation of oversized fragments leads to additional crushing costs, while excessive pulverization can cause a portion of the iron, titanium, and vanadium minerals to be lost with technological waste. Therefore, achieving an optimal granulometric composition should be adopted as the primary criterion when designing blasting operations. The use of electronic detonators and digital blasting systems has been confirmed to allow for high-precision control of blasting processes. Blasting sequences with millisecond accuracy enable control over the rock mass deformation process, direction of the blast energy, and an increase in the recovery coefficient of valuable components. The implementation of these technologies at the Tebinbulak deposit will serve to reduce ore dilution and increase extraction efficiency. It has been substantiated that applying three-dimensional geological modeling and geomechanical simulation methods at the deposit expands the potential for predicting blasting outcomes. Individual blasting designs developed based on geological block models allow for the precise consideration of ore and waste rock boundaries, optimizing energy consumption, and minimizing the loss of valuable components. Additionally, ore displacement processes resulting from blasting were analyzed. It was determined that tracking post-blast displacement and integrating it with geological models helps to increase the accuracy of excavation contours. This prevents some of the ore from being left unmined or being discarded with waste rock. By optimizing blasting operations at



the Tebinbulak titanomagnetite deposit, it is possible to significantly reduce the loss of valuable components such as iron, titanium, and vanadium. The introduction of differentiated blasting technologies, based on geological data, electronic detonators, digital modeling systems, and modern monitoring methods, serves to increase the economic efficiency of the mine, improve ore quality indicators, and create a high-quality raw material base for the metallurgical industry. The results obtained during this study hold significant scientific and practical importance for improving the scientific and methodological foundations of blasting operations management in the development of titanomagnetite and iron ore deposits, ensuring the complex and rational use of mineral resources, and implementing sustainable mining principles in practice.

CONCLUSION. In conclusion, it has been determined that the scientifically-based management of blasting operations at the Tebinbulak titanomagnetite deposit is a crucial factor in reducing the loss of valuable components and increasing the overall economic efficiency of the mine. The research findings indicate that blasting processes should be regarded not merely as a means of crushing rock mass, but as a key technological stage that shapes ore quality indicators. Studies have revealed that titanomagnetite ores possess high strength and density, a condition that significantly affects the distribution characteristics of blast energy throughout the rock mass. It has been substantiated that the incorrect selection of blasting parameters can lead to the intermingling of ore and waste rock, a decrease in the quantity of valuable components, and a deterioration in ore quality. Therefore, the necessity of using differentiated blasting technologies that account for the specific characteristics of geological blocks has been identified.

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