ORE LOSS AND DILUTION IN THE SUBLEVEL CAVING

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Abstract. This article discusses the direct dependence of ore loss and dilution indicators on the mining method and the dimensions of its constructive elements in underground mining of mineral deposits, as well as their significance in managing production indicators. The method for reducing loss and dilution during the extraction of caved ore in a caving mining method, and their impact on the efficiency of the mining enterprise, are also highlighted. The study explores the potential for increasing labor productivity, shortening the block preparation period, and reducing the total length development workings through the optimization of the mining method's constructive dimensions.

Keywords: caving mining method, extraction block, loss, dilution, ore drawing, blasting layer, mine workings.

Annotatsiya. Ushbu maqola foydali qazilma konlarini yer osti usulida qazib olishda ruda nobudgarchiligi va sifatsizlanishi ko‘rsatkichlarining qazib olish tizimiga, uning konstruktiv elementlari o‘lchamlariga bevosita bog‘liqligi va ularning qazib olish ko‘rsatkichlarini boshqarishdagi ahamiyatiga bag‘ishlangan. Shuningdek, ruda va atrof tog‘ jinslarini qulatib qazib olish tizimida qulatilgan rudani chiqarib olishda sodir bo‘ladigan nobudgarchilik va sifatsizlanish ko‘rsatkichlarini kamaytirish usullari hamda konchilik korxonasining samaradorligiga ta’siri yoritilgan. Qazib olish tizimining konstruktiv o‘lchamlarini optimallashtirish orqali mehnat unumdorligini oshirish, qazish blokini tayyorlash davrini hamda tayyorlovchi, kesuvchi kon lahimlarining umumiy uzunligini kamaytirish imkoniyatlari o‘rganilgan.

Kalit so‘zlar: qulatib qazib olish tizimi, qazish bloki, nobudgarchilik, sifatsizlanish, rudani chiqarish, qulatiladigan qatlam, kon lahimlari.

Аннотация. Данная статья посвящена анализу зависимости показателей потерь руды и её разубоживания при подземной разработке месторождений полезных ископаемых от системы разработки и размеров её конструктивных элементов, а также их роли в управлении показателями извлечении. Также освещены методы снижения потерь и разубоживания при выпуске обрушенной руды в системе разработки с обрушением руды и вмещающих пород, а также их влияние на эффективность горнодобывающего предприятия. Изучены возможности повышения производительности труда, сокращения периода подготовки блока и общей длины подготовительных выработок за счёт оптимизации конструктивных параметров системы разработки.

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Ключевые слова: система разработки с обрушением, выемочной блок, потери, разубоживание, выпуск руды, отбиваемый слой, горные выработки.

Introduction.

Over the past quarter century, the demand for mineral resources has increased significantly relative to the growth of the world population, and at the same time, the regulatory requirements governing mining activities have continued to tighten (Figure 1) [1]. The rational and safe extraction and use of mineral resources is an issue of state policy, and the necessity of ensuring its implementation is reflected in legislative norms [2]. Accordingly, complex utilisation of the subsurface, the recovery of economically viable reserves as fully as possible, and the application of rational, environmentally safe technologies are among the priority tasks of mining operations.

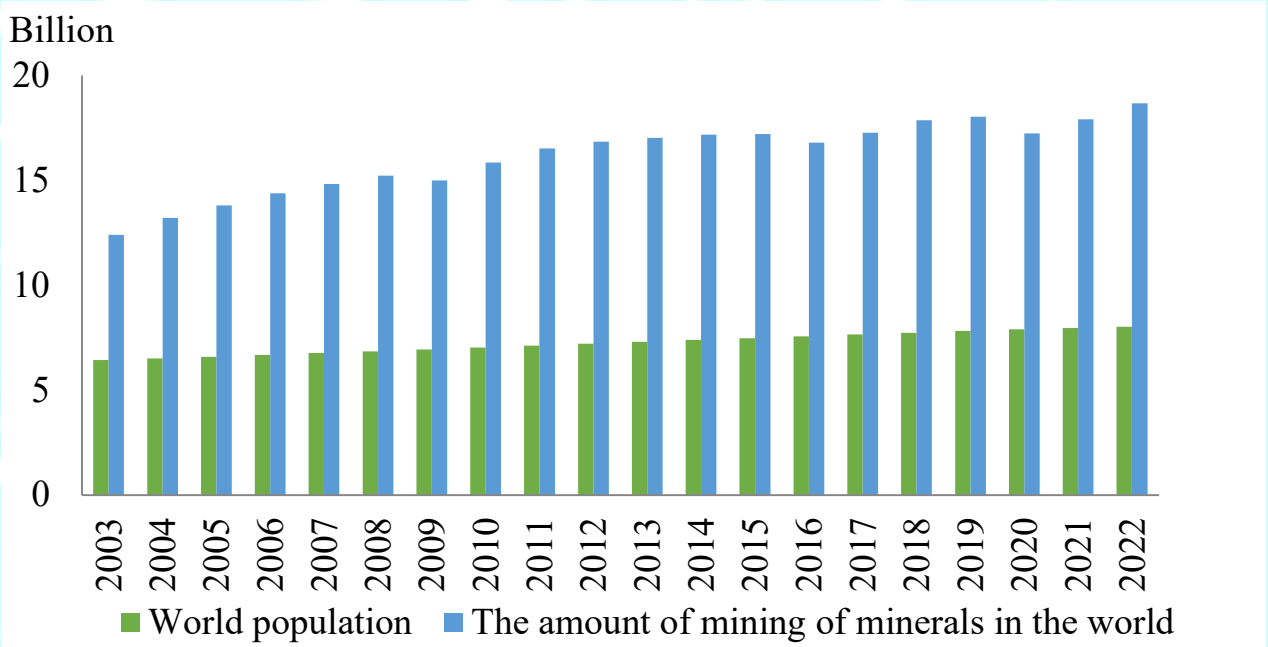


Figure 1. Diagram illustrating the relationship between global population growth and the volume of extracted mineral resources

One of the principal requirements in the extraction and processing of mineral resources is to prevent ore loss and dilution [3]. Controlling normative ore loss and dilution is achieved by selecting, on a sound technical-economic basis and taking into account mine-geological and mining-technical conditions, the most appropriate, safe and efficient mining method.

Among the underground mining methods, one of the most widely used method is the sublevel caving mining method. The main reasons for its prevalence are the simplicity of technological operations and the high production capacity. Nevertheless, this extraction method is associated with relatively greater ore loss and dilution.

The factors affecting recovery performance are multiple, and those that can be managed include the constructive elements of the mining method. The

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constructive elements of the sublevel caving mining method are: the height of the sublevel, the distance between ore extraction drifts (or drawpoints), and the thickness and dip (inclination) of the seam to be mined [4].

To date, no specific scientific laws have been established to justify the optimal thickness of the caving ore layer, the drilling and blasting parameters, the height of the sublevels, or the spacing between the drifts to minimize ore loss and dilution [5]. These parameters are applied only as recommendations tailored to particular mining conditions. Considering this, the following aspects require deeper investigation and development of fundamental relationships: the dependence of ore loss and dilution on the development layout for block extraction; the theoretical principles of extraction from beneath caved rock masses; the influence of sublevel caving mining method on ore loss and dilution.

Experimental research. Based on the results of studies carried out at several mining enterprises to increase the efficiency of extraction methods and improve ore recovery indicators, modification of the constructive parameters of the extraction method was proposed as the most optimal solution. [6,7]. In the present study, increasing the sublevel height, increasing the distance between ore extraction drifts, and altering the dip (inclination) angle of the rhomboidal panel (Figure 2) are considered the principal solutions to ensure higher recovery performance.

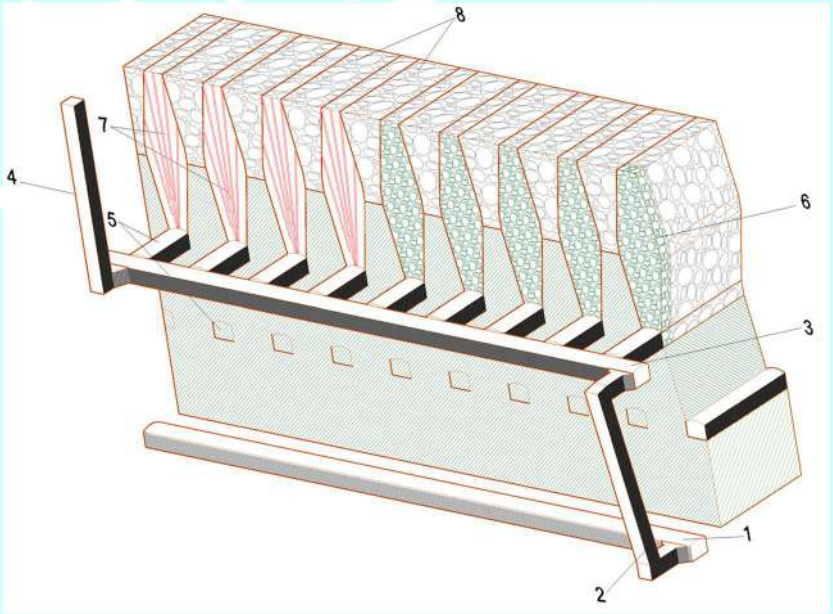


Figure 2. The scheme of the sublevel caving mining method
1– haulage drift; 2 – orepass; 3 – sublevel drift; 4 – raise; 5 – sublevel crosscut; 6 – caved ore seam; 7 – blasthole charges; 8 – caved country rocks

Sublevel drifts and sublevel crosscuts, when positioned at specific distances from one another, form rhomboidal panels. In a rhomboidal panel, mining operations begin with the drivage of the cutting drift, which creates the cut slot. Ore removal from the confined medium is carried out by blasting boreholes

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arranged in a fan-shaped pattern [8]. Depending on the orientation of the boreholes within the extraction panel, the mined seam's dip may be vertical, inclined toward the rock mass, or inclined toward the caving mass.

During the processes of drawing caved ore from the panel, secondary ore loss and dilution occur. In the initial stages of drawing a certain amount of clean ore is recovered. As the number and quantity of draws increase, country rock is progressively mixed with the ore mass, and eventually the ore drawing declines until only country rock is produced. The loss and dilution during panel extraction depend on the quantity of clean ore recovered at the drawing. The clean ore yield, in turn, is governed by the ellipsoidal dimensions that develop during the drawing process [9].

Changes in the dip angle of the mined seam affect the movement characteristics and governing laws of fragmented ore pieces, as well as the dimensions of the ore-drawing ellipsoid. Variations in the height of the caved seam and the spacing between ore-draw drifts also lead to an increase in the size of the drawing ellipsoid.

To comprehensively evaluate the factors influencing ore loss and dilution during panel extraction, a study was conducted. In this research, the ore drawing process was examined using three visual models of different sizes, allowing observation of the interaction and mixing between ore and country rock.

Research results. According to the analysis of the obtained experimental results, when the dip angle of the blasting seam is directed vertically or toward the rock mass, the caved country rocks exert greater pressure on the ore. As a result, during the ore drawing process from the panel, ore loss and dilution are relatively higher [10].

When the dip angle of the blasting seam is oriented toward the caved rock mass, however, the pressure of the caved country rocks on the ore is lower, and consequently, ore loss and dilution are comparatively reduced.

Initial data on the amount of ore mass extracted from the block were obtained from laboratory model studies, and the processing of measurement results was carried out in several stages:

• preliminary processing of the data to provide a detailed assessment of the main parameters and conditions of ore drawing;

• preparation of a results table and constructing of various correlation graphs.

The ore drawing results are presented in Table 1.

Table 1

Indicators of loss and dilution during ore drawing

№	Dip angle α, ˚	Loss, %	Dilution, %
I Model	80	11,6	42,1

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	100	7,4	91,3
II Model	80	8,7	19,2
	100	13	170
III Model	80	5,8	63,4
	100	30,1	187,3

Based on the processing of data obtained from laboratory tests, correlation graphs of ore drawing indicators were constructed for three models.

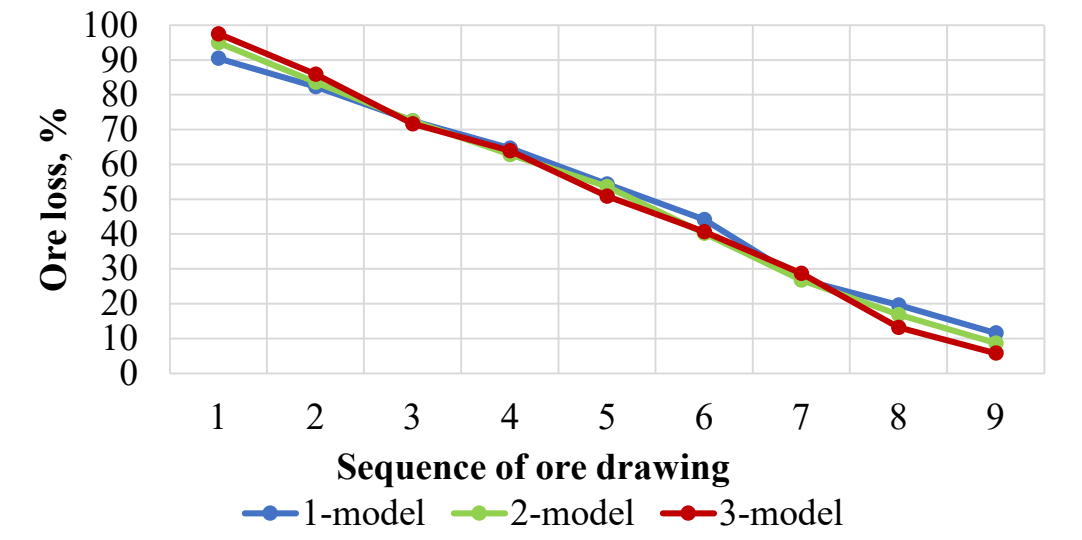


Figure 3. Ore loss when the dip angle of the caving seam is 80°

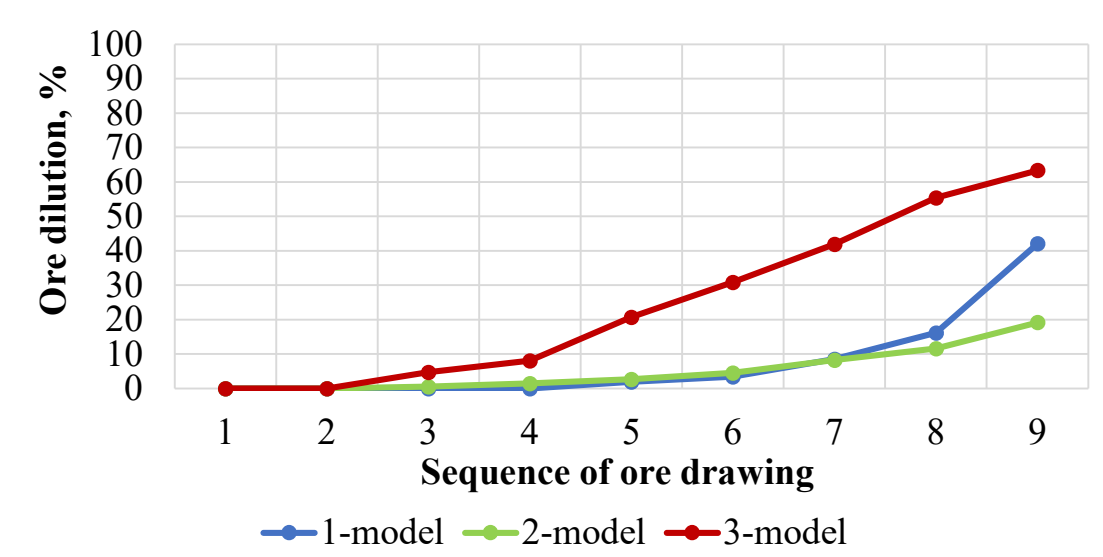


Figure 4. Ore dilution when the dip angle of the caving seam is 80°

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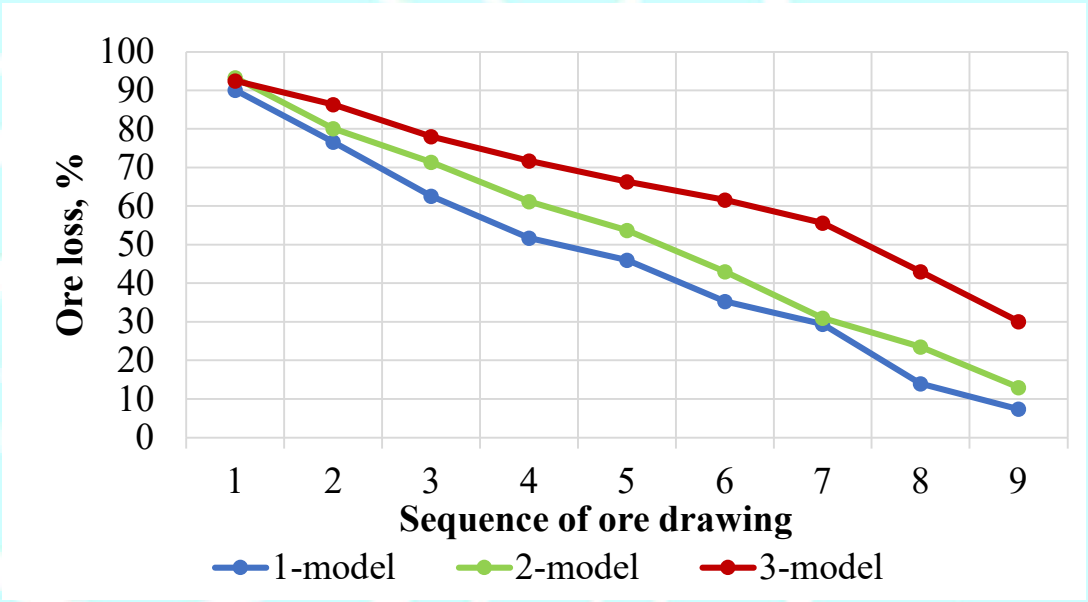


Figure 5. Ore loss when the dip angle of the caving seam is 100°

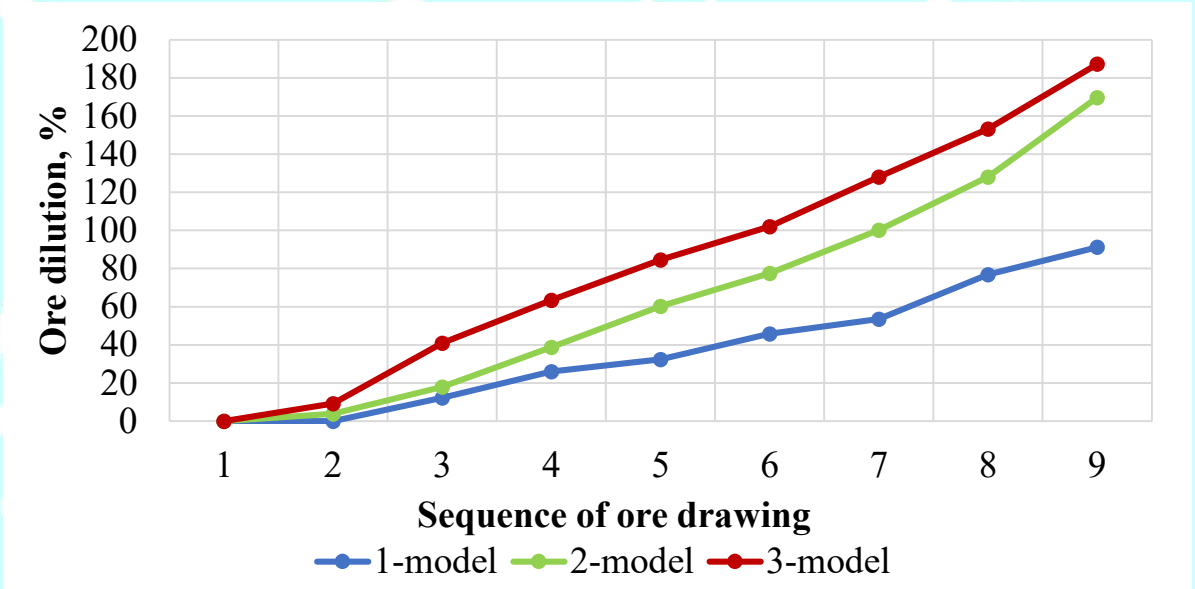


Figure 6. Ore dilution when the dip angle of the caving seam is 100°

Although there are several methods for assessing the economic efficiency of mining systems, their constructive parameters, and newly implemented technologies, the method based on comparing the economic damage caused by ore loss and dilution, as well as material and labor costs, was applied due to its reliability and simplicity.

Conclusions. Based on the conducted research, the following conclusions were drawn: it was established that, in addition to the conventional mine-technical factors, the dimensions of the constructive elements of the mining method have an influence on the indicators of ore loss and dilution. Increasing the sublevel height and the distance between ore extraction drifts (spacing) leads to an enlargement of the ore extraction ellipsoid, which, in turn, results in a reduction of ore loss and dilution. The results of the techno-economic analysis indicate that the proposed method offers a number of advantages, including a high level of rational subsurface

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use, low economic damage from ore loss and dilution, reduced volume of development works, lower expenditures on materials, energy, and labor, as well as shorter development period of the block prior to extraction.

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