GOSPODARKA SUROWCAMI MINERALNYMI

Tom 18 2002 Zeszyt 4

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Technological aspects of dilution in Polish copper ore mines

Key words

Ore dilution, yield, profitability, thickness of deposit

Abstract

The paper presents tendencies of development and change in mining technology of copper ore deposits over thirty years of experience. Technical aspects of formation and minimization of the dilution processes in Polish copper ore mines, whose total yearly output amounts to 28—32 million tonnes of copper ore, have been thoroughly analyzed.

Introduction

Ore mining costs, mining losses and dilution are those three main factors which, apart from the price, are decisive for the effectiveness of deposit resources mining.

It is known, both from mining practice and theory that the largest dilution takes place while mining **thin deposits**. It is mostly the result of the specific production process, equipment used and many other factors which will be discussed further in the paper.

In Poland, a deposit having the thickness of deposit below 1.5 m is considered to be thin. At present, it is estimated that in Poland ca 60% of copper resources have the depth of deposit around 2.0 m and nearly 20% of them are 2.0 to 2.8 m thick. No wonder, that dilution process is a significant problem.

Average dilution of the ore mined by KGHM in the years 1991—2001 was (diagram 1):

— "Lubin" mine — 14,43%,

— "Polkowice" mine — 21,69%,

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Reviewed by Prof. Roman Magda

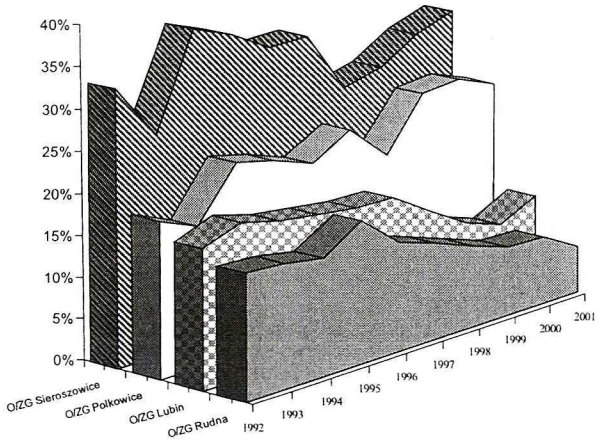

Fig. 1. Ore dilution in KGHM mines over the years

Rys. 1. Zubożenie rudy w KGHM na przestrzeni lat

— "Rudna" mine — 11,91%,

— "Sieroszowice" mine — 31,04%.

The ratio of thin deposits compowe to entire ore reserves is as follows in individual mines:

— "Sieroszowice" mine: thin bed makes up ca 80% surface,

— "Polkowice" mine: thin bed makes up ca 35%, of deposit surface,

— "Lubin" mine: thin bed makes up ca 20%, of deposit surface,

— ca 48% of reserve deposit surface — for Lubin mine, "Małomice" area is made up by thin deposit.

As it can be seen form the above list, the problem of thin deposit concerns mainly two mining areas, which are mined by O/ZG "Polkowice-Sieroszowice" and a reserve area of Lubin--Małomice mine.

1. Dilution classification in KGHM Polska Miedź S.A.

A very diversified morphology of the deposit roof and floor is a characteristic feature of copper ore deposit mining. This causes difficulties in matching mining excavations geometry to deposit geometry. The consequences are on one hand natural ore dilution and losses in deposit roof and floor.

In KGHM Polska Miedź S.A. mines dilution classification of the ore suited to their specific geological-mining conditions is used (Table 1). Here we have the division into GROUPS, PHASES AND TYPES.

Generally, dilution size in KGHM mines is influences by many factors resulting from:

— geological conditions of ore run,

— mining systems,

— rules of deposit management.

TABLE 1

Classification of ore dilution adjusted for deposit-specific conditions used in KGHM Polska Miedź S.A.

TABELA 1

Klasyfikacja zubożenia rudy stosowana w KGHM Polska Miedź S.A. dostosowana do specyficznych warunków górniczo-geologicznych

Groups	Phases	Types
Division acc. to mine organisation structure	Division acc .to ore mining technological structure and measure points of metal contents	Division acc. to reason of dilution
1. Face — deposit plot	1.1. Ore mining	a. Mixing with industrial ore of impoverishing rocks b. Unidentified metal losses (quality losses)
2. Flat — mining flat	2.1. Ore mining	
3. Mines — mining plant	3.1. Ore mining 3.2. Loading and haulage to ore chutes conveging, hoisting, surface transport	
4. General deposit — company	4.1. Ore mining 4.2. Loading and haulage to ore chutes conveging, hoisting, surface transport	

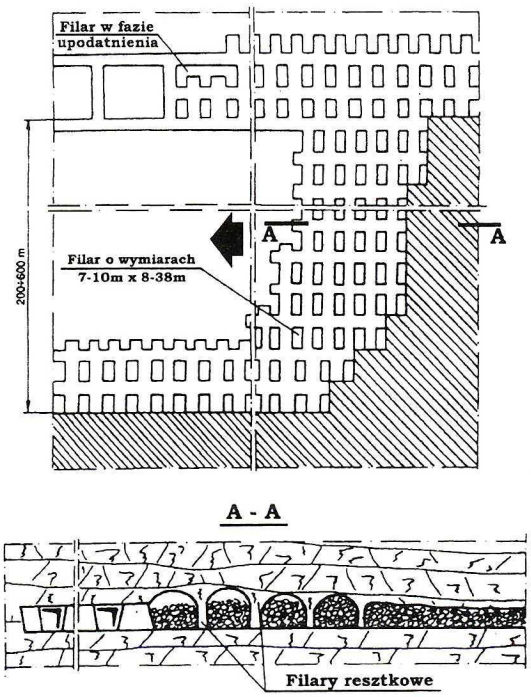

Fig. 2. Outlay of a room-and-pillar method used in the LGOM basin

Rys. 2. Schemat systemu komorowo-filarowego stosowanego w LGOM

Observations of movement, considerable experience of the thirty years' mining of the copper ore deposit and alot of theoretical work connected with the subject provided the basis for the investigations which were undertaken in the 90-ties. They showed that ore dilution depends largely on:

— thickness of deposit,
— natural deposit split,
— average thickness of deposit of banks of the direct roof (responsible for roof quality).

Room-and-pillar mining systems are widely used for mining copper ore deposits (Fig. 2). They allow full mechanization of mining works, large mining concentration and high productivity. Mining of deposit with these systems is characterized by high flexibility which enables adapting the system to local geological-mining conditions.

2. Reasons for formation and technological methods of fighting dilution at KGHM

Investigation and mining practice show that 80 to 90% of all dilution cases are caused by rippings of all possible types.

Reasons of formation and technological methods of fighting dilution in Polish copper mines are presented in table 2.

3. Mining the thin deposit at KGHM Polska Miedź S.A.

As it was shown above, the problem of mining the thin deposit concerns mainly two mining areas where mining is conducted by O/ZG "Polkowice-Sieroszowice". For some time in this mine the average thickness of the deposit has been going down (Fig. 3) which makes it necessary to lower the opening.

Under such conditions, the mining process is done as follows:

— first, low protile machines (not higher than 1.85 m) are used
— second, by changing the mining system into the so-called selective mining (with waste rock disposed of in mined out aweas).

Both solutions have their advantages and hazards. It will be discussed later in the paper.

3.1. Mining the thin deposit using low mobile machines

In copper mines, ore is mined with explosivos. Diesel — powered LHD machines and tuchsare are used for. Machines which were introduced many years ago were basically identical in all the mines of LGOM. They were high, i.e. they enabled deposit mining with the mining port higher than 3 m. When the depth of the deposit diminishes and the height of the mining port remains at the level necessary for "high machines", then the height of the port exceeds the thickness of the deposit and ore dilution grows. The basic method of minimizing this process is lowering mine openings.

TABLE 2

Roots and management of dilution process in Polish copper mines

TABELA 2

Przyczyny powstawania i technologiczne metody zwalczania procesu zubożenia w polskich kopalniach miedzi

RIPPING OF WASTE ROCKS AND UNECONOMICAL ORE	
ORIGINS	Technological methods to counter
— during mining in excavations of the height greater than balance thickness of deposit; — resulting from variable formation of mineralized parts of deposit in its profile; — at diversified floor and roof morphology, small corrugations of faults; — resulting from the presence of weakly compact rashings of roof rocks becoming loosened, etc.	— adequate choice of mining systems and equipment, corresponding to balance of the mined deposit thickness. — selective mining of useful ore and waste with the possibility of placing the latter in mined out areas
DEPOSIT DISCONTINUITY, BARREN INTERLAYERS	
ORIGINS	Technological methods to counter
— development works in uneconomical ore and in waste rock; — due to rochbursts in mining areas	— contour blasting which secure disturbance of rock cohesiveness: hard surfaces of exposed rocks, — protecting out of contour rocks, mainly roof ones against disintegrating influence of blasting works (formation of stratifications, bank slips, roof cracks, etc.) mainly from the time of uncovering roof and side walls till their development
ROCK CONTAMINATION WITH WASTE ROCKS AND OFF-BALANCE ROCKS	
ORIGINS	Technological methods to counter
— revamping of development headings; — during relining of excavation roof; — during uncontrolled falls of roof; — rock rise coming from technological roof caving, row of technological pillars	— when mining is done in areas of rich tectonics, whose *roof is made up of thin-banked calciferous or marl (silty and streak) dolomites* — mining should be done without forcing roof fall with blasting works. It limits the number of uncontrolled falls of roof in excavations and roof rippings, thus diminishing ore dilution
SCATTER AND SEGREGATION OF OUTPUT	
ORIGINS	Technological methods of FIGHTING
— *blasting*; — *ore loading and haulage (small, but high grade parlicles get lost)* — Mainly in headings, unloading and transfer points and ore stockpiles	— Use of blasting patterns to prevent scatter of output, especially cupriferous shales, — Thorough recovery of blasted ore in mine headings, — Mining and cleaning of burrow, booster points and storage places of small fractions of output

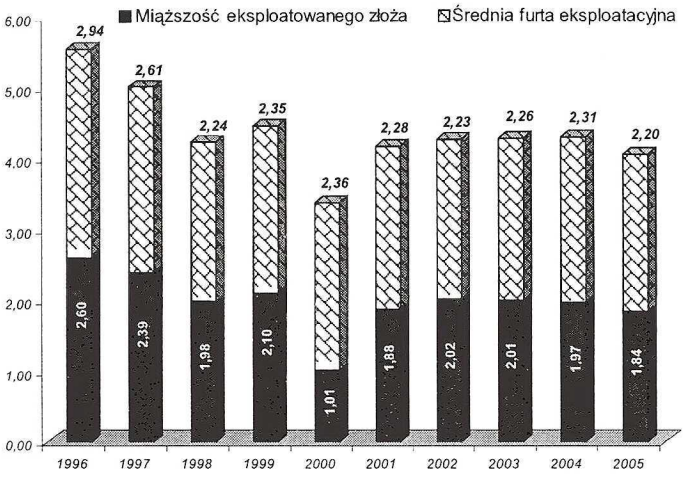

Fig. 3. Comparison of the average deposit thickness and excavation seams in Polkowice-Sieroszowice Mine in the years 1996—2000 and forecast until the years 2005 r.

Rys. 3. Zestawienie średnich miąższości eksploatowanego złoża i furt eksploatacyjnych w kopalni Polkowice-Sieroszowice w latach1996—2000 i prognoza do2005 r.

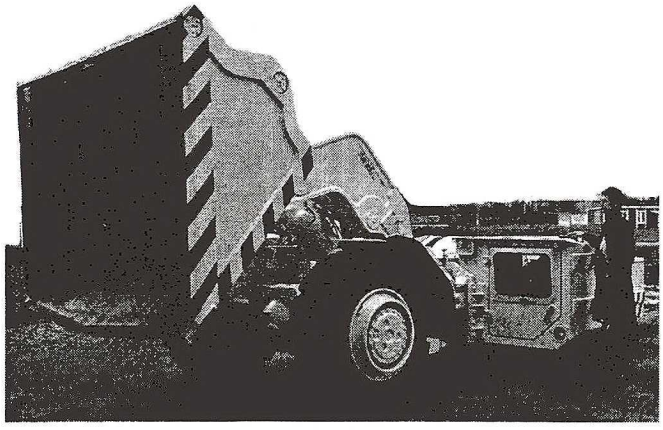

Fig. 4. Loader LKP 0900 enabling mining thickness of the deposit 1.6 m made by DFM ZANAM Polkowice (POLAND)

Rys. 4. Ładowarka LKP 0900 pozwalająca eksploatować złoże o miąższości od 1,6 m produkcji DFM „ZANAM" Polkowice (POLSKA)

Machines cannot be lowered endlessly therefore application of the so-called selective mining seems an interesting alternative to this technology.

3.2. Selective mining

The largest dilution occurs in the case of thin and non-continuous deposit. Here appears the problem of choosing the appropriate mining system, suited to this type of deposit and designing

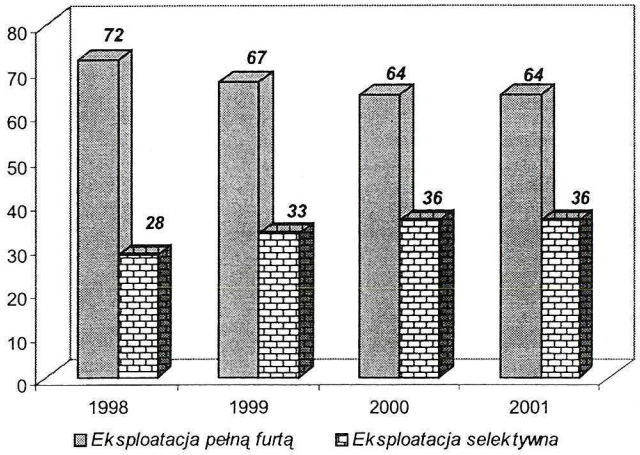

Fig. 5. Percentage of selective mining in output of Polkowice-Sieroszowice Mine

Rys. 5. Udział eksploatacji selektywnej w produkcji O/ZG Polkowice-Sieroszowice

such excavation geometry (height of the port) which will take into consideration deposit morphology. Obviously, selective mining and processing of cupriferous shales seems desirable because of the high content of copper and accompanying metals in them.

Selective mining which is being used more and more often seems to be a solution. In this method, one web is mined in two stages. The first stage comprises mining and getting the ore from the heading, in the second one waste rock is processed. There are many technological variations of this method.

At present, in the most mining flats of "Polkowice-Sieroszowice" mine selective deposit mining is done at different degrees — from several heading to the whole front.

Depending on the thickness of the deposit, the so-called selective mining with a "deposit sill" for the thickness below 1.5 m and selective mining with a "stone shelf" for the depth higher than 1.5 m are done.

1. Selective mining with a **"deposit sill"** (Fig. 6)

This methods is basically used in the deposit up to 1.0 m deep with a significant content of cupriferous shales in the deposit profile. Excavations of specific sizes are made according to blasting matrices in the waste rock above the bed. Then, the heading which was blasted selectively with a deposit sill is mined: blasted stone is mined, the heading forehead and stone side walls over the deposit sill are precisely cleaned, later, thickness deposit sill is mined. The height of the deposit sill R is the depth of the deposit and a protective layer 0.2—0.3 m thick above the deposit. After having mined the waste rock, the ore from the deposit sill should be taken to a burrow hole.

2. Selective mining with a **"deposit sill"** (Fig. 7)

This method is used for deposits thicker than 1.0 m and thinner than 2.0 m and in the deposit deeper than 2.0 m where roof conditions make driving the excavation roof on the deposit roof impossible. This method covers two cycles.

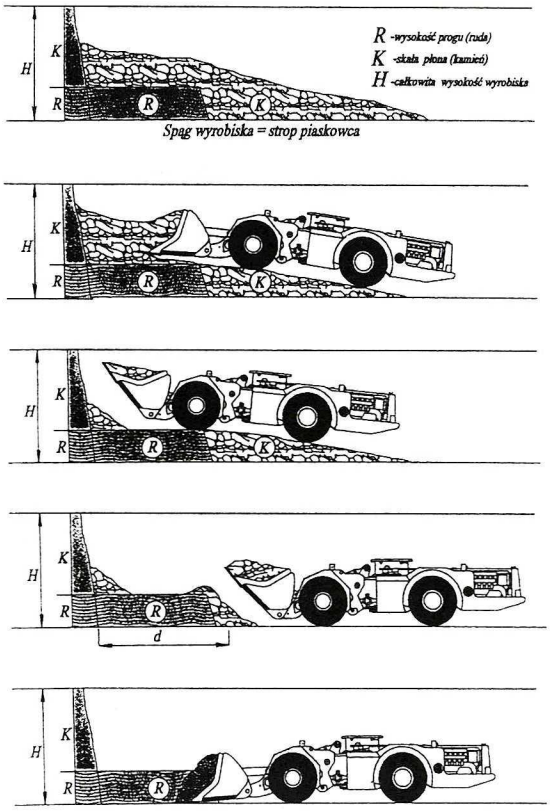

Fig. 6. Stages of selective mining of a thin deposit using ore bench

Rys. 6. Wybieranie cienkiego złoża metodą selektywną z progiem złożowym

Cycle I comprises *deposit mining*, i.e. making excavations of specific sizes according to blasting matrices (drilling and blasting works) in the deposit. After having checked whether a stone shelf did not fall on the blasted deposit, the output is mined (keeping the proper slope of side wall planes).

Cycle II is *stone mining* i.e. mining of stone shelf, getting stone output and placing it in a closed down area. It should be pointed out here that during blasting in the stone part rocks that are in the deposit below become cracked. Particular care should be kept while mining stone in the heading forehead in order to avoid mining ore together with stone. After mining the stone the cracked part of the deposit should be mined and taken to the burrow point.

Selective mining technology has its obvious advantages, but also there are drawbacks. One of the most important ones is mining large quantities of waste rock. It gets separated during blasting and then it is transported to its location. If selective mining is conducted at the mining area, then waste is placed in mined-out greas which are not very far. However, if these methods are applied to development headings then waste has to be hauled over long distances from the excavation resulting in extra costs.

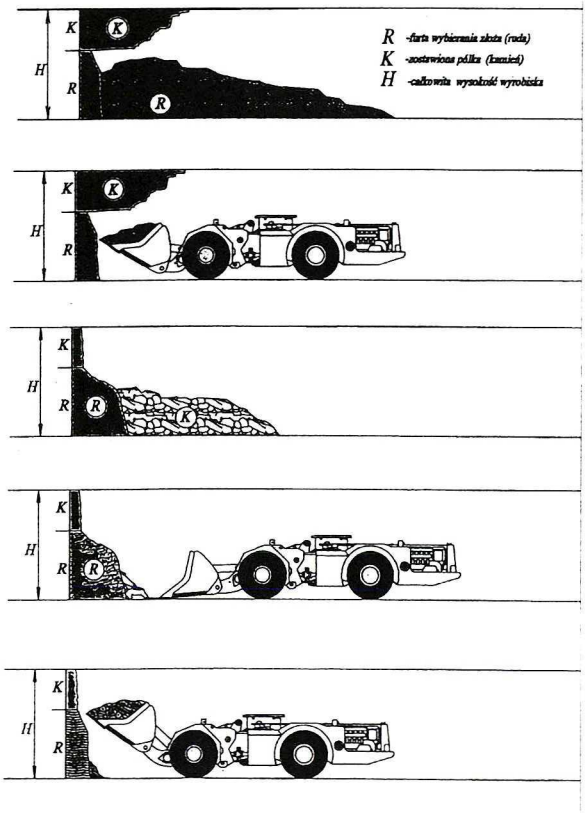

Fig. 7. Selective mining of a thin deposit using separate blasting of waste lager

Rys. 7. Wybieranie cienkiego złoża metodą selektywną z półką kamienną

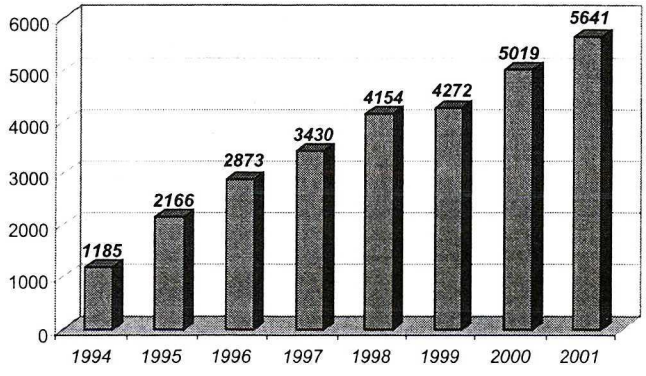

Fig. 8. Amount of waste rock located in the underground of the mine Polkowice-Sieroszowice

Rys. 8. Ilość kamienia ulokowana na dole kopalni „Polkowice-Sieroszowice"

Fig. 8 shows the problem of stone mining and storage during ore mining in "Polkowice--Sieroszowice" mine.

In 2000 and 2001 more than 5 mln tonnes of waste rock were placed in the mine. It is more than 50% of the ore mined by O/ZG "Polkowice-Sieroszowice."

Conclusions

Activity of copper mining industry in market economy requires quick and smooth adapting both deposit management and all the components of the process to world standards. It is connected with the necessity of analyzing ore mining costs and undertaking activities aiming at solving important technical and technological problems.

It should be clearly stressed that dilution process as such is an unfavourable phenomenon.

The paper has shown that large quantities of stone are separated during ore mining in "Polkowice-Sieroszowice" mine. The stone is placed in old works. It seems to be a pro-ecological activity since it eliminates stone storage on the surface and diminishes the waste amount to be utilized.

On the other hand, activities aiming at lowering the mining port, i.e. optimizing its height and minimizing dilution are connected with significant costs which cannot often be eliminated.

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TECHNOLOGICZNE ASPEKTY ZUBOŻENIA W POLSKICH KOPALNIACH RUD MIEDZI

Słowa kluczowe

Zubożenie, uzysk, miąższość złoża

Streszczenie

W referacie przedstawiono tendencje rozwoju i zmiany w technologii eksploatacji złoża rud miedzi w świetle ponad trzydziestoletnich doświadczeń, szczegółowej analizie poddano techniczne aspekty powstawania i minimalizacji procesu zubożenia w polskich kopalniach rud miedzi, których łączne wydobycie w skali roku kształtuje się na poziomie 28—32 milionów ton.