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AN INNOVATIVE WAY OF UNDERGROUND MINING

All engineering solutions in ore mining have their starting point, when the very idea of development of a new deposit appears. The creation of the required market for one or another commercial product extracted from the subsoil remains one of the most significant factors in development of civilization in the 21st century and, therefore, needs effective and preventive management of the condition and evolution of the production framework for the mining and metallurgical sector.

Based on the foregoing, the conclusions have been made, that make it possible to create optimal conditions for the use of mineral raw materials in the development of the economy of the future, including modification of underground mining technologies which should radically change both from the standpoint of maintaining the natural balance of the subsoil and ecological cleanliness, as well as the comprehensive and maximum possible extraction completeness.

One of the most optimal factors that effectively influence creation of a modern mine image is the underground mining technology and organization. The article shows the advantages of using the bottom-up method of mining, when mining operations create a bottom-up stoping front not within one horizon as in the traditional concept, but conditions accessing of an ore body to the full depth and subsequent stoping in ascending series from the lower boundaries of the ore body (or whole deposit). The proposed method can be successfully applied in the hybrid technology with simultaneous and / or sequential use of open-pit and underground methods.

Accessing via haulage ramps using self-propelled equipment in case of the bottom-up mining method enjoys a new application domain since it simultaneously takes on the role of ubiquitous operational exploration, because the ramps can be cut in ore, which allows stoping already during mine construction. At the same time, the volumes of waste rock excavation are significantly reduced.

The proposed method of mining solves the important problems of reducing losses and dilution, increasing economic efficiency, including decrease in the capital costs and in the time of capital return, while ensuring mining safety and maintaining the natural balance of the subsoil.

Keywords: *underground mining method, haulage ramp, stoping area control, operational exploration, capital costs, losses and dilution*

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Introduction

Involving science to solving urgent and interrelated problems set by representatives of public institutions and business, or initiation of researchers by scientists and engineers themselves will help to get the maximum benefit from the use of advanced materials and new technologies. But in any case, the fulfillment of all desires and requirements of human civilization, which in the contours of future and already created technologies will determine new opportunities, will depend on the availability of mineral raw materials in the Earth’s bowels, which should be efficiently extracted and processed. This governs the creative role of mineral raw materials in the history of mankind.

The requirements imposed on the final results, which should generalize joint efficiency of mineral extraction and primary processing in the form of concentrates at ecological purity and completeness of use of natural resources, in turn, are the functional derivative of the created and selected schemes for the extraction of minerals from the subsoil and their processing, which are composed of process flows known in mining and processing.

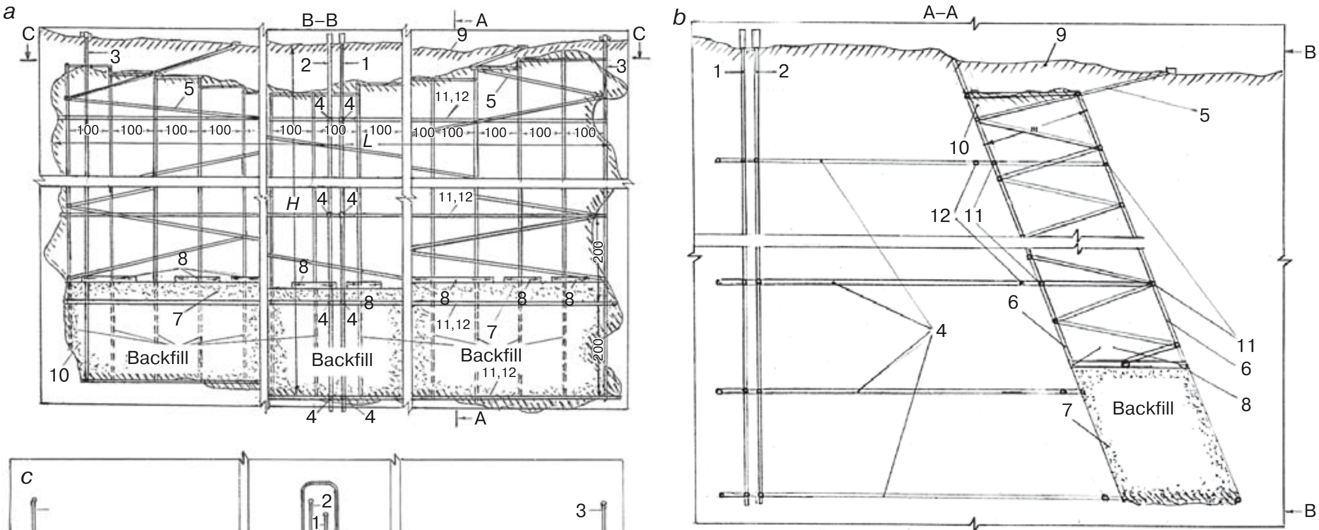
The main target function of mineral extraction can be fulfilled given the access is provided from the earth’s surface to the ore occurrence, therefore, the development of a mineral deposit begins with the choice of the methods of accessing and extraction. The accessing process flow is included in mining if the underground method is chosen [1].

Underground mining can be carried out top-down and bottom-up in the whole deposit and in its separate parts divided along the height [2]. The choice of the method and technology of mining toward effective mineral production is extremely important and decisive in terms of taking into account requirements imposed on the final results of mineral use in the mine project.

The analysis and definition of the main directions for technological development in mineral mining and processing proves that the existing and operating technological processes in mining and processing need significant improvement and must meet the requirements of a new era which is characterized by complication of mining conditions. Proceeding from this, the technological schemes, depending on geological and geotechnical conditions, should be created on the basis of a new approach to the underground mining method [3–6].

The apparent need to open up a deposit to the full depth of industrial mineralization is almost always unrealized, since the desire to ‘not freeze’ capital costs and to get profit as soon as possible by cutting minerals top-down prevails over the more optimal bottom-up method when assessing total operating time of the field [7].

In fact, in most cases, the full-depth access and bottom-up mining makes it possible to avoid a number of negative consequences of top-down mining.



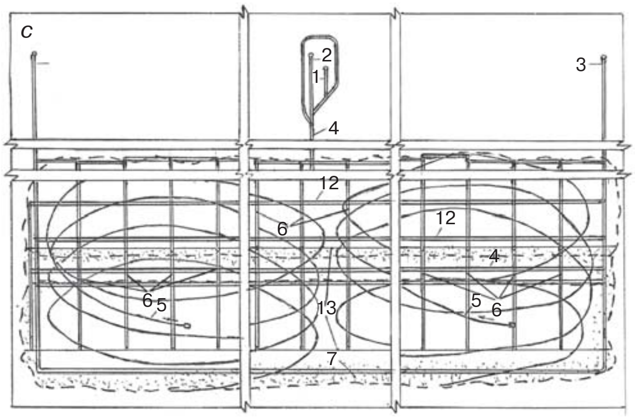


Fig. 1. Bottom-up underground mining method (option for steeply dipping thick ore bodies):
1–Cage shaft; 2–Skip shaft; 3–Ventilation shaft; 4–Crosscut; 5–Haulage ramp; 6–Block raise; 7–Backfill; 8–Stopes; 9–Surface; 10–Ore body; 11–Rift drift; 12–Gangways; 13–Stoping boundary

Methods

The top-down method accelerates the start of field exploitation and, at the same time, causes extra project-unaccounted losses of minerals during mining. Such losses arise from the need to leave unmined ore between horizons (superstructure and substructure pillars) and from the excessive dilution of ore (mixing with waste rock collapsing from barren sidewalls at the ore–rock mas interface) [8, 9]. Other disadvantages of the top-down approach, which is currently used everywhere, are:

- simultaneous accessing, preparation and mining using the same transport routes (horizontal and vertical), which interferes with other various purpose operations;
- inability to increase production capacity and constant increase in production costs due to gradual and continuous increase in the depth of mining because of depletion of ore reserves on the upper horizons.

The proposed bottom-up process flow diagram allows avoiding the above listed disadvantages as it [10]:

- eliminates expenses connected with maintenance of long-term serviceability of horizontal and vertical excavations serving for the transport of rocks, inlet and outlet of fresh and exhaust air, delivery of materials, equipment, people, since mining operations do not descend vertically but go upward;
- greatly reduces volume of waste rock excavation;
- minimizes losses and dilution since bottom-up mining eliminates exposed roof in mined-out space, which in the vast majority of cases remains below and is filled with waste rock and cemented mixtures;
- enables higher labor productivity due to the continuous use of self-propelled and other equipment, and the production costs are reduced;
- allows enhancing production capacity due to increased capacity of haulage routes because of decrease in the volume of waste rock to be transported and owing to withdrawal of the haulage routes from construction work;
- enables combining the open pit, especially in accessing via adits and extracting mineral in an upland quarry, and the underground mining methods, including continuous backfill at minimum cement consumption [11].

One of the possible process flow diagrams of mining operations is shown in **Fig. 1**. At the same ascending method of mining, the process flowcharts can be various, subject to geological conditions, while the advantages of the proposed method are preserved [12, 13].

Results and discussion

The calculations show another critical economic and technological advantage of the bottom-up method. At present, accessing of mineral deposits is commonly organized via haulage ramps from top to bottom using self-propelled diesel equipment. In this case, the ramps are cut in foot wall as stoping proceeds from top to bottom, and it is necessary to maintain the ramps for the entire life of the mine. In bottom-up stoping, the state of the ramps is independ of the rock mass stresses induced by mining, and a ramp itself is not an obstacle to lower-level stoping. Thus, accessing along the ore body makes it possible to extract additional amount of ore instead of barren rock, enables advanced operational exploration to define more precisely the ore body outline and the hidden geological disturbances, allows reducing stone drivage owing to decreased depth of access shafts and shorter length of access crosscuts.

It should be emphasized that additional advantages of the bottom-up method of mining are the following factors that have not yet been taken into account, namely:

• the capital costs will be equal to the design estimates, while with the top-down method, all the time you have to find additional sources to cover extra expenses, since an operating mine often has to stop main production in order to organize capital construction using fixed assets to sink blind shafts, or to cut ore and rock passes, and ventilation openings;

• the capital construction cost has a justified increasing tendency over time due to inflation and unforeseen expenditures and, therefore, in case of breaks in advance of mining on underlying horizons, the capital costs increase both in absolute and in relative terms.

The upward mining involves technologically thought-out and cost-minimized solutions to the issues connected with:

• underhand backfill using the known portable materials, at minimal water and cement consumption and minimum cost (backfill pipeline can be laid either in a specially made raise or along a haulage ramp;

• ore haulage by ramps and operating area ventilation when mining is advanced from center to sideways and the haulage ramp is in the center of the ore body and when mining is advanced from sides to the center and the ramps are cut on the sides;

• development of the mining process flowchart in the horizontal plane, depending on thickness and dip angle of the ore body.

Mining alternatives will also arise depending on the occurrence of one ore body or a number of ore bodies in the mine field, and subject to their interposition.

The specified scheme of ore body accessing via ramps at the ramp section of 20 m^2, minimum ramp length of 1000 m per each vertical 100 m and at the bulk ore weight of 2.7 t/m^3 makes it possible to extract 54000 tons of pure ore during construction period and allows precise outlining of an ore body before mining start. When it is necessary to simultaneously open up intermediate layers in the accepted cascade horizons, the amount of ore can multiply, including drivage of horizontal headings aimed to determine the true values of the strike and thickness of the ore body. Moreover, the process flow diagram allows accurate determination of all geological disturbances and their parameters, with inclusion of these data into stoping project [14].

The need to drill vertical shafts (cage, skip), and side ventilation shafts is conditioned by the length of the deposit along the strike and dip, by the required production output and by the geological characteristics of the deposit (presence of separate ore bodies and their positional relationship).

Conclusions

The developed and proposed process flow diagram of ore body accessing and mining using high-angle conveyors can enable transition to cyclic-and-continuous haulage of ore from stopes to ground surface for processing, with arrangement of coarse crushing in underground conditions.

With a view to implementing the bottom-up underground mining method in a specific ore field, it is required to:

• Estimate applicability of the technology in the given geological and geotechnical conditions;

• Substantiate the production necessity, economic efficiency and technological feasibility of the bottom-up mining procedure with geomechanical design of pillar-less extraction;

• Create efficient non-stop bottom-up mining flowcharts with minimal losses and dilution, and, depending on horizontal thickness of ore bodies, to design stope faces to be in simultaneous operation to ensure drilling-and-blasting, mucking, ventilation and stoping control in case of continuous stoping front;

• Create a classification of underground bottom-up mining systems.

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