Ore stream management on the development of deposits of natural and technogenic origin

Cite as: AIP Conference Proceedings **2432**, 030061 (2022); https://doi.org/10.1063/5.0093311
Published Online: 16 June 2022

Shukhratulla Ochilov, Voxid Kadirov, Azamat Umirzoqov, et al.

Ore Stream Management on the Development of Deposits of Natural and Technogenic Origin

Shukhratulla Ochilov[a)], Voxid Kadirov[b)], Azamat Umirzoqov[c)], Askar Karamanov[d)], Shaxboz Xudayberganov[e)], and Izzatbek Sobirov[f)]

Tashkent State Technical University named after Islam Karimov, 2, University str., 100095, Tashkent, Uzbekistan

[a)]*Corresponding author: shuxratulla.ochilov@tdtu.uz*
[b)]*voxid.qodirov@tdtu.uz*
[c)]*azamat.umirzoqov@tdtu.uz*
[d)]*karamanov.asqar@tdtu.uz*
[e)]*azamat.umirzoqov@tdtu.uz*
[f)]*azamat.umirzoqov@tdtu.uz*

Abstract. In the development of the complex-structured Muruntau deposit, in the prospective way, there is a clear tendency to an increase in the depth of the open pit, a decrease in the conditions for salable ore, the involvement of off-balance ore warehouses accumulated in the process of mining, the transition to continuous modes of transport. This article focuses on the significance of ore stream management and development of deposit of natural and technogenic origin that can have a great role to get more information about ore stream. Also, this paper is based on the transition to a simplified selective-bulk mining of ore zones with the allocation of the main and stabilizing front of mining operations makes it possible to control the qualitative and quantitative characteristics of the ore flow during the development of deposits of natural and technogenic origin.

Keywords: Muruntau deposit,ore, mining production, mining operations, mining blocks, fluctuations, natural and technogenic origin

INTRODUCTION

A specific feature of complex-structured deposits is a significant uneven distribution of the useful component in the ore mass. Moreover, this unevenness is the higher, the further from the center of the ore body. In practice, this means that if the sampled volume of ore is divided into many elementary volumes, the useful component can be concentrated in only one of them, and the existing methods and tools for determining and assessing reserves allow them to be identified only within the entire volume. That is, a certain amount of waste rock is deliberately involved in processing, and on the other hand, part of the reserves is thrown away together with waste rock. This feature makes the task of creating ore flow quality control systems at various stages and levels of development of complex-structured deposits urgent and economically feasible.

As a result of the research, it was established that the quality control of the ore flow in the cyclical-flow technology of the development of complex-structured deposits should be implemented on the basis of a systematic approach and the use of a complex of discrete and continuous methods of recognition and sorting of rock mass at hierarchically interconnected levels of the natural-industrial system "deposit-quarry-plant ". Each of the levels of the system is characterized by the degree of reliability of the assessment of the quantity and quality of the useful component. In a sense, each level determines the stage of the system research. The purpose of each stage is to select objects for further research at a lower level of the system. Each level has its own economically and technically rational methods of recognizing and sorting the allocated objects.

At the stage of exploration of the deposit, on the basis of geological documentation and sampling, ore bodies with their own features of material composition are outlined. At this level, delineation and calculation of stocks is carried out. On the basis of conditions, balance and off-balance reserves are allocated. The next level of the system is a quarry, which corresponds to the stage of operational exploration and development of the deposit. On the basis

The 1st International Conference on Problems and Perspectives of Modern Science
AIP Conf. Proc. 2432, 030061-1–030061-6; https://doi.org/10.1063/5.0093311
Published by AIP Publishing. 978-0-7354-4345-7/$30.00

of the results of operational testing, the contours of ore bodies are refined and varietal plans are drawn up with the allocation of various types of ores. Areas of overburden and mining blocks are identified.Through normalization of losses and dilution on the basis of economic criteria, the optimal height of the worked bench is calculated, the yield of commercial ores and their quality are determined. These calculations serve as the basis for planning mining operations. On the basis of geological documentation and technological sampling, the technological properties of ores are established. Among the mining blocks, there are blocks with technologically homogeneous ores. Different grades and technological types of ores are mined separately and shipped to the appropriate reloading or off-balance storehouses. Features of the separation of off-balance ores during the development of complex-structured deposits: dispersed mineralization in the host rocks and contact zones of ore bodies make it possible to represent the storage of off-balance ore as a mixture of lumps of balance ores and waste rocks. This feature makes possible the express separation of the ore mass into ore and rock based on indirect signs. Based on the results of the lump sorting, the ore mass is sent to the transshipment warehouse for shipment to the plant, the rock is taken to the dump. The transshipment warehouses of the open pit are used to form a stream of ore flow that is uniform in terms of the content of the useful component and technological properties.

Each warehouse accepts ore of a certain quality in accordance with the warehouse passport. Ore is supplied to the plant from transshipment warehouses in accordance with the shipping specifications. The required quality is achieved by adjusting the volumes of ore mass shipment from various warehouses. The application of a systematic approach objectively puts the factory redistribution as the last and final link in the chain of recognition and sorting of the ore mass. After loading the ore from the trains into the feeder bunker, further ore homogenization is carried out when it is fed to the mill blocks.

The final stabilization of the ore flow is achieved on the sorption feed. Based on the sampling data at this stage, the optimal parameters and consumption of reagents are determined to achieve the maximum extraction of the useful component (Figure 1). Moreover, the average grade in the processed ore should not be lower than a certain level. The choice of the optimal direction for the development of mining operations, which ensures the extraction of ore with a given level of quality, is the most important condition for the formation of an ore flow and is carried out on the basis of a mining-geometric analysis of the placement of quality properties of ores in the depths. In the deep quarry of Muruntau, it begins with testing. For these purposes, drilling and blasting wells are used, which are drilled on ore blocks along a network of 5.6 x 5.6 m. The depth of the wells is determined by the height of the bench being worked out and is 10.0 - 15.0 m. Samples are taken from each well for analysis with a sampling interval of 5.0 m. Sampling is carried out directly during drilling using a special three-slot sampler, which allows preliminary reduction of material in the process of sampling up to 10-15 kg. Due to the fact that the excavation contours of various ore grades are determined only from sampling data, operational sampling and digital data processing are the most important link in planning and accounting for mining.

METHODS

The solution to this problem is the express analysis of samples and software-mathematical methods of information processing, implemented, respectively, in the laboratory of gamma-activation analysis and the computer-aided design system for technological preparation of mining production (CAD TP GP). The results of the analyzes of the samples are transferred to the geological service, where, by means of geostatic assessment, various types of ores and rocks are outlined on working plates. In accordance with the monthly mining plan, a graded plan is issued for each excavator, on which the contours of ore bodies are highlighted.

According to the graded plan, the surveyor marks the blasted mass and the excavator driver dispatches it according to the specified grades and warehouses. The graded plan serves as the basis for monitoring the treatment works, determining and recording losses and dilution during mining, calculating the content in the ore supplied to the transshipment points of the open pit (PPK). Based on these calculations, current planning and stock management of the quarry is carried out.

The control system for the ore flow and the movement of reserves in a quarry is a set of subsystems of "preparation of reserves", "development of reserves", "accounting of reserves", "preparation of warehouses for the formation of an ore flow of a quarry-plant".

The first three subsystems are implemented in the CAD TP GP in the mode of engineering preparation and support of mining operations. Further development of computer technologies and the use of modern technical means made it possible to carry out operational management of the development of reserves and the shipment of ore from warehouses and was implemented in the ACU KR and AT based on GPS (an automated system for managing the quality of ore flow and road transport).

The interaction of CAD TP GP and ACS KR and AT allows to optimize the quality of ore from the open pit for further processing. Optimization of the management of the unloading of the ore mass from the open pit is achieved by using a single database along the chain from the open pit to the receiving bunker of the GMZ. The use of FPC containing different grades of ores in the sectors allows mixing and averaging them, providing the optimal grade for the GMZ. Ore from different areas (PPC sector or open pit mines) can be formed into an ore flow, taking into account the different physical and chemical properties of ore grades, depending on the design plan. The specified operating mode can be provided with ore from the PPK, or from the PPK and from the working faces.As the ore is supplied, the database is refined and the operating modes can be dynamically changed, reflecting fluctuations in the incoming ore grades and rocks. Thus, as a result of the research, it was established that the quality control of the ore flow in the cyclical-flow technology of the development of complex-structured deposits should be implemented on the basis of a systematic approach and the use of a complex of discrete and continuous methods of recognition and sorting of rock mass at hierarchically interconnected levels of the natural-industrial system “deposit-quarry plant ". A prerequisite for the transition to simplified mining of ore bodies is a steady decrease in the grade in the processed ore, which is caused by a decrease in the share of high grade ore in the total ore mass. The consequence of such a decrease in grade is a decrease in the cut-off grade, which is close to the grade in the tacked off-balance ore, which significantly reduces the effect of losses and dilution on the quality characteristics of the ore being mined.At the same time, the requirements for managing the quality of the ore flow in the open-pit mining of complex-structured deposits are increasing, which is based on the use of a complex of discrete and continuous methods of recognition and sorting of rock mass at hierarchically interrelated levels of the “deposit - opencast - warehouse” system.

The general task of controlling the parameters of the ore flow is to supply the ore to the processing plant in a given quantity and a given quality. At the same time, fluctuations in the content in the ore should not exceed the limits corresponding to the capabilities of the technology and excluding unjustified losses of useful components during processing.Thus, with a high variability of the content in the mined ore, the averaging of the ore mass becomes essential. Based on the principle of continuous control of the quality characteristics of the ore flow, the process of ore mass averaging can be divided into the following characteristic stages:

- planning of mining operations for a certain period of time (quarter, month, week, day, shift, hour);
- operational regulation of the ore flow rate from each face (inter-face averaging);
- formation of intermediate warehouses with ore of average quality;
- shipment of ore from intermediate warehouses to maintain the specified parameters of the ore flow "quarry-plant";
- final mixing of portions of ore entering the plant in an intermediate hopper, which is a buffer tank, in mills, thickeners, and in sorption columns.

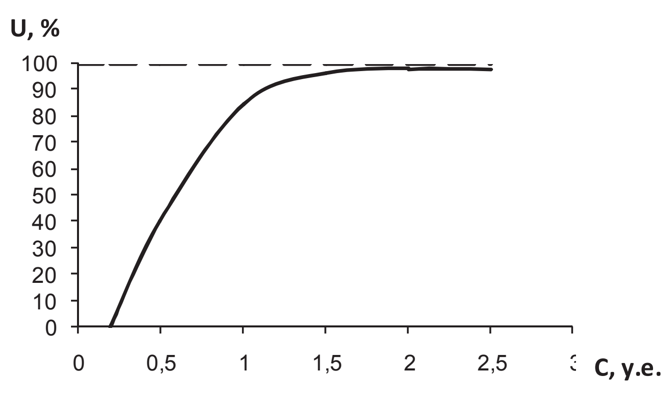

FIGURE 1. Dependence of recovery on the average grade in the processed ore

Thus, the averaging of the grade in the ore occurs throughout the entire technological chain of the "open pit - plant" system (Figure 2). In this system, the plant is regarded as a powerful blending machine, capable of completely eliminating high-frequency fluctuations and significantly smoothing low-frequency fluctuations in the grade in the incoming ore.

At the same time, the amplitude and wavelength of low-frequency oscillations are determined by the ability of a specific sorption technology to "take a hit" with an increased content in the supplied ore, preventing excess gold losses in the processing tailings. It is this ability that is the second main prerequisite for the

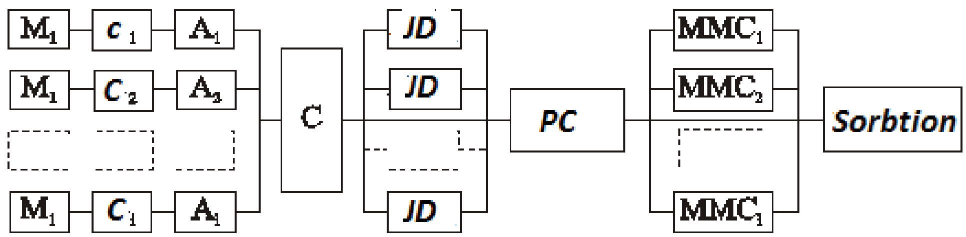

FIGURE 2. Scheme of ore flow averaging in the "quarry-plant" system

transition to a simplified mining of ore bodies. Naturally, the conditions for sorption leaching have changed significantly, primarily due to an increase in processing volumes and a decrease in the average grade in the ore. However, the retention capacity of the technology has increased, mainly due to a decrease in the grade in the processed ore, which is confirmed by practice.

Thus, at the mining complex there are prerequisites for the transition to a simplified mining of ore zones, based on a decrease in the gold content in the processed ore and the ability of the sorption technology to maintain standard gold losses with an expanded range of fluctuations in the quality characteristics of the ore flow. The management of the quality characteristics of the ore flow is based on the regulation of the amount of ore mass mined in different zones. At the same time, elementary ore flows from each face are combined into flows of ore zones, with the help of which the transfer points of the open pit are filled.It follows from this that with the probabilistic nature of the distribution of the gold content in the massif, the state of the excavation and loading equipment, dump trucks and the order of their unloading at the PPK, the controlled parameter is the amount of ore mass extracted in each face, and the control means is the size of the excavator and the number of dump trucks in operation. Thus, quality control of cargo traffic is achieved by regulating the number of production faces in simultaneous operation and the productivity of mining equipment. Then the problem is reduced to finding such a mode of joint operation of excavators that ensures the minimum deviation of the contents from the planned values at any given time interval. From a mathematical point of view, the solution to this problem is reduced to one class of nonlinear programming.

Let's introduce the following designations: - planned content in the ore mass discharged from the open pit for the GMZ; - the actual content in the **j**- entry of the **i**- excavator; - deviation of the metal content in the **j**- run of the **i**- excavator;

F_k^{γ} - the average deviation of the metal content in the ore with the simultaneous operation of **n** excavators at the **k**-step of mining blocks;

F k - the average deviation of the content in the ore stream with the simultaneous operation of n excavators at **k** steps of mining blocks.

Then the objective function will have the following mathematical expression:

$$\frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\alpha_{ij}}{k} - \alpha_n \to \min \qquad (1)$$

The deviation of the metal content in the **j**- run of the **i**- excavator is determined from the expression:

$$R_j^i = \alpha_{ij} - \alpha_n \qquad (2)$$

The average deviation of the metal content during the simultaneous operation of n excavators at the **k**-step of mining the mining blocks is determined from the expression:

$$\mathbf{F}_{\mathbf{k}}^{\gamma} = \frac{\sum_{i=1}^{n}\sum_{j=1}^{m}\mathbf{R}_{\mathbf{j}}^{\mathbf{i}}}{\mathbf{n}} \tag{3}$$

The average deviation of the metal content in the ore stream during the simultaneous operation of n excavators at k steps of mining blocks is determined from the expression:

$$\mathbf{F}_{\mathbf{k}}^{\mathbf{total}} = \frac{\sum_{1}^{k}\mathbf{F}_{\mathbf{k}}^{\gamma}}{\mathbf{k}} \tag{4}$$

The existing scheme for the formation and quality control of the ore flow in the quarry was created at a time when a set of equipment of excavators with a bucket capacity of up to 8 m3 and dump trucks with a carrying capacity of up to 75 tons were used in excavation and transport operations. The geometrical parameters of the bucket (width up to 2 m) allowed for selective notch with sufficient accuracy. Currently, excavators with a bucket with a capacity of 26 m3 and dump trucks with a carrying capacity of up to 220 tons are used in the quarry. The scheme for managing the quality of the ore flow has changed accordingly (Figure 3).

Quality control of the ore flow during the transition from selective to bulk mining of ore zones cannot be reliably implemented only by maneuvering the number of faces and equipment productivity. This situation is explained by the fact that it is not possible to fully synchronize the operation of individual faces without disrupting the balance of mining and stripping operations in complex-structured fields with a variation of 200% or more. Therefore, a part of the faces cannot be stopped or put into operation only for reasons of ensuring the qualitative or quantitative parameters of the ore flow.

As a result, it is inevitable that situations where high-grade or low-grade ore will be mined in excess of the amount required to maintain the grade in the ore stream at a given level. Therefore, such a situation is considered as an inevitable technological element accompanying the development of a complex-structured field and capable of having a positive or negative impact on the efficiency of its development. It is proposed to neutralize the negative influence of this technological element as follows.

Mining blocks are divided into two groups.The first group includes blocks with low and medium content, from which the "main production front" is formed. The second includes blocks with a high content, from which a "stabilizing production front" is formed. Block-by-block planning and subsequent monitoring of compliance with the planned preparation and development dates are applied only to blocks of the stabilizing production front. Therefore, the planning goal is to ensure a constant proportion of high-grade blocks in the overall structure of the production front. Mining operations in the blocks of the “main production front”, supplying the bulk of the ore, require only the total productivity, therefore, specific terms and development are of fundamental importance only for maintaining the balance of mining and stripping operations. Fluctuations in quality that may arise in this case are compensated by blocks of the “stabilizing production front”. The severity of the problem of confirming the quality of ore in blocks remains only for blocks of the "stabilizing front". If during the preparation process it turns out that in a certain block of the "stabilizing front" of mining the quality of ore is lower than required, such a block is transferred to the "main production front" and another with a high metal content is introduced instead.

CONCLUSION

In conclusion, the transition to a simplified selective-bulk mining of ore zones with the allocation of the main and stabilizing front of mining operations makes it possible to control the qualitative and quantitative characteristics of the ore flow during the development of deposits of natural and technogenic origin. In this case, the range of fluctuations in the contents is ± 14.5%, which corresponds to the capabilities of the sorption technology of the processing plant and can be taken as an evaluation criterion in the formation of the ore flow "open pit - plant".

REFERENCES

1. Nasirov, U.F, Ochilov, S.A, Umirzoqov, A.A. Theoretical calculation of the optimal distance between parallel-close charges in the explosion of high ledges. *Journal of Advanced Research in Dynamical and Control Systems,* 2020; **12**(7 Special Issue): pp. 2251–2257.
2. Nasirov, U.F., Zairov, Sh.Sh., Ochilov, Sh.A., Ravshanova, M.Kh., Ergashev, O.S. Method to make a shielding slot in pit wall rock mass using non-explosive destructive mixture. *Mining Informational and Analytical Bulletin,* 2021; (3):pp.72–82.
3. Norov, Y.D., Nasirov, U.F., Ochilov, S.A. Investigation and development of high-bench blasting method with parallel close-spaced holes and wedging stemming. *Gornyi Zhurnal,* 2018; (9):pp. 42–45
4. Norov, Yu.Dzh.,Nasirov, U.F., Bibik, I.P., Norov, Zh.A., Normatova, M.Zh. Manufacturing of blasting operations in complex hydrogeological conditions. *Gornyi Zhurnal,* 2013; 8(1): pp. 30–31.
5. Rajmzhanov, B.R., Norov, Yu.D., Nosirov, U.F., Makhmudov, A.M. Forming the trench cartridge of explosives in water saturated soils during excavating explosion. *Gornyi Zhurnal,* 2003; (8): pp. 55–57.
6. Mahmadoliev AK, Makhmudov DR, Nurboboev YT, Pardaev FS. Reducing the cost of backfill in the Kauldi gold mine. InIOP Conference Series: *Earth and Environmental Science* 2020 Dec 1 (Vol. 614, No. 1, p. 012058). IOP Publishing.
7. Sanakulov, K.S., Umarov, F.Ya., Shemetov, P.A. Technical and economic efficiency of application of high angle conveyor at Muruntau open pit. *Gornyi Zhurnal,* 2013; 8(1):pp. 17–19.
8. Umarov, F.Ya. Energy efficiency enhancement problems and prospects of coal use in power engineering in Uzbekistan. *Gornyi Zhurnal,* 2013; (7):pp. 23–25
9. Umarova IK, Matkarimov ST, Makhmarezhabov DB Development of a flotation technology for gold-bearing ores of the Amantaytau deposit. "ObogashchenieRud", *Обогащениеруд*. 2020;29–33.DOI; 10.17580/or.2020.02.05
10. Zairov SS, Makhmudov DR, Urinov SR. Theoretical and experimental research of explosive rupture of rocks with muck piles of different geometry. *Gornyi Zhurnal,* 2018, No. 9. DOI.;10:46-50.
11. UmarovFYa, NasirovUF, NutfulloevGS, NazarovZS, SharipovLO. Increasing the efficiency of underground mine workings using borehole charges with a cumulative effect. Proceedings of higher educational institutions. Mining Journal. 2020 (3): pp. 15-23.
12. Shemetov PA, Nasirov UF, Ochilov SHA. Rationalization of the technological scheme for the development of mining operations in the Muruntau open-pit mine. Mining information and analytical bulletin (scientific and technical journal). 2014 (8).
13. Ochilov SHA, Kotsareva NK, Jumaniyazov DD. Development of technological schemes and justification of the parameters of intermediate buffer temporary warehouses when they are dumped on the platforms of the open pit benches. InReproduce of the resources, low-waste and environmental technology exploitation of mineral resources 2015 (pp. 123-125).
14. Rakhimov VR, Shemetov PA, Nasirov UF, Ochilov SHA. Methodology for choosing the best options for the development of small-scale and technogenic gold deposits. Mining information and analytical bulletin (scientific and technical journal). 2014 (6).
15. Nasirov, U. F. (2017). Ochilov Sh. A., Ravshanova MH Theoretical studies of the mechanism of crushing rock rocks with the explosion of high ledges. *IzvestiyaVysshikhUchebnykhZavedenii. Mountain magazine.-Ekaterinburg: ed. UGSU*, (3), pp. 38-44.
16. Vorobev AE, Nasirov UF, VorobevKA.IDENTIFIED GOLD NANOFORMS IN GEOGENIC AND TECHNOGENIC MINERAL RAW MATERIAL.GorniyvestnikUzbekistana. 2020;2020(1):10-7.
17. Killinger A. Status and future trends in suspension spray techniques. *InFuture Development of Thermal Spray Coatings* 2015 Jan 1 (pp. 81-122). Woodhead Publishing.
18. Hawk C, Sullivan E, Yu Z, Liu S. Developments in Metal Additive Manufacturing. *Welding journal.*2020 Feb.
19. Jou GL, Ju YL, Wang JW, Hsieh C, Yam SC. Aeronautical Knowledge (Selected Articles). *FOREIGN* TECHNOLOGY DIV WRIGHT-PATTERSON AFB OH; 1981 Feb 19.
20. Corcoran E, editor. Sick water?: the central role of wastewater management in sustainable development: a rapid response assessment. *UNEP/Earthprint;* 2010.