Blasting preparation for selective mining of complex structured ore deposition

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Abstract. Technological features of ore mining in the open pit development for processing of complex structured ore deposit of steeply falling occurrence have been considered. The technological schemes of ore bodies mining under different conditions of occurrence, consistency and capacity have been considered and offered in the paper. These technologies permit to reduce losses and dilution, but to increase the completeness and quality of mined ore. A method of subsequent selective excavation of ore bodies has been proposed. The method is based on the complex use of buffer-blasting technology for the muck mass and the principle of trim blasting at ore-rock junctions.

1. Introduction

The development of rare earth and precious metals deposits is carried out by the complex technological process, since, such deposits often consist of heterogeneous mineralization structure. Typical features of such deposits are: irrigularity of thickness of the seam bearing and dipping with the heavily disturbed bedding, the presence of seam swelly and wedging-out, debris interbeds; unstability of the quality of the mineral and uneven distribution of the metal.

Taking into account the dynamics of the world rare-earth and precious metals markets, as well as the cost of materials and labor, the manufacturer seeks to optimize the parameters for the extraction of high-grade ores. Manufacturers have introduced the methods for 100% extraction of ore reserves from the mineral wealth and increased the production and processing of non-commercial reserves as well.

The level of ore loss and dilution in quarries of rare-earth and precious metals is determined by the quality of rock mass preparation for the excavation (the degree of mixing and the displacement of ores and rocks during the explosion) and the purity of the ore mass digging.

The issues of losses and dilution standardization should include the following main tasks: operational testing and constructions of high-quality planning, blasting and excavation operations, the choice of effective blasting schemes, using ignition schemes of charges taking into account the ore bodies location. It is necessary to save the historical, geological ore structure and to reduce displacement of ore bodies and rocks at a blasting point to a minimum as well as to achieve excavation and shipment of shot rocks [1].

The effective and rational method of the blasting with further selective excavation of ore in complex geological conditions is one of the main methods of reducing costs for technological cycles of excavation and ore processing [2, 3].

2. Materials and methods
The theoretical and methodological basis of the paper is the comprehensive approach. It includes the analysis and generalization of the fundamental research of the authors in the field of open pit mining of steeply dipping rare earth and precious metals deposits, the analysis of losses and dilution methods for determining, normalizing and accounting them, as well as the experience in quarrying with complex structure of ore bodies.

Technological solutions of excavation preparation and processing of excavation deposits with complex structure mineralization in order to reduce losses and dilution during mining and to increase the completeness and quality of mined ore have been considered in the paper.

A technology of rock blasting, including steeply dipping of ore bodies and intermediate rock to a selective excavation, has been offered. The technology is based on the buffer-blasting technology for muck rocks and the trim blasting at ore-rock junctions.

As a result of the buffer explosion technology, a high degree of crushing is achieved, which is expressed in low percentage of the out-of-gauge yield. As a result of the trim blasting technology at the ore-rock junctions, mixing useful components with rocks on the deposit side is minimized.

3. Technological solutions preparation of rocks for excavation

One deposit may be represented by different conditions of occurrence such as the consistency and thickness of the ore bodies. Taking into account the high value of the useful component, it is necessary to extract minerals more efficiently and to prevent or minimize the damage from losses and dilution of mined ore. In order to reduce losses and dilution of mineral raw materials the quality management should be used with help of special technological solutions for preparation and mining operations. The technology of separate excavation in the shotpile permits to reduce losses and dilution during mining and to increase the quality of mined ore.

An example of the rare-earth deposit section demonstrating features of several ore bodies (OB) occurrence is shown in Fig. 1. The width of the ore zone at several ore bodies is usually about 50 - 60 m, the distance between ore bodies is from 2-3 m up to 5-30 m [4].

![Figure 1. A typical section along the deposit](image)

The complex structure of mineralization requires a higher level of mining technological processes, both mining preparation and ore mining. Therefore, the excavation of ores from blasted complex blocks is always accompanied by the separate extraction of ore for processing and by the heap leaching technology of non-industrial (poor) ores and gang mineral. Separate excavation of the blast rocks can be simple or complex. It is desirable to extract ores under the following basic conditions [5-7]:

- blasting of rock and ore is carried out mainly by the bulk or complete method of mining;
- the position of the “ore-rock” junction and ores grades are determined by the Geological Survey with the pegs setting on the shotpile;

Rock mass excavation in the complex face is always carried out in the direction from the hanging wall of the ore bodies to the footwall, with the least loss and dilution of ores. The development of the ore bodies from the footwall of the deposit to the hanging wall is prohibited;

Depending on the deposits, the development of the mining bench must be provided with two
subbenches of 5-meter and with the division of a subbench 5-meter high. To increase the level of selective excavation in the development of poor ore bodies, the bench 5-meter long can be worked out by 2.5 m excavation layers;
- in accordance with the technology of the bulk blast, all three sizes of the blast block (width, length and height) or some of them are installed regardless of the junction and the ore bodies amount;
- initially, part of shotpile is shipped along the roof of the bench, with the drifting from the hanging wall side of the ore body.

To reduce losses and dilution, it is advisable to use the technological scheme with backhoe type excavators. The example of the excavation of two ore bodies subbench using the PC-400 excavator has been presented in Fig. 2. The technology includes sequential mining first the rocks by the subbench at the side of the hanging wall, then the ores.

Stage 1

Stage 2

Figure 2. The technological scheme of the face mining with backstops by the backhoe type excavators

When the buffer blasting methods for muck rock mass and trim blasting of the ore-rock junction are used, the method of the rock blast preparation for selective excavation can be applied in the open development. The open developments are steeply dipping deposits for the mining conditions and avaluable deposits with complex-structural mineralization Fig. 3 [8, 9].

Figure 3. Blast preparation scheme for selective excavation, where: I - the buffer from muck, II – the series of wells; III - the proposed ore deposit; IV – the extension well; V - the final position of the bench after blasting.

The ore blocks shattering with the use of the buffer blast method is carried out mainly by the multirow blasting in the wedging-out. Multirow blasting with the delay intervals of 50-75 ms in the wedging-out space provides more complete preservation of the ore bodies deposit after the explosion due to a lower fracturing rate after the explosion (Kp = 1.05 ÷ 1.2, rarely higher). The energy output of the excavation and the duration of excavation cycle increase the specific consumption of explosives.

Blast in the wedging-out space involves the use of the network scheme with longitudinal and
transverse cuts. The row order schemes are applicable only for the solid rocks with intensive fracturing, for strong mid-block rocks. It is more efficient to use diagonal and radial schemes. A feature of drilling and blast preparation is the thickening of the well grid by 10-15% and the limiting of minimum width of the blast block (at least 5-6 rows of wells).

Blast in wedging-out space (with relieving wall, with the buffer) decreases the degree of fragmentation in the lower part of the shotpile to $K_\text{r} = 1.03 \div 1.08$, and in the middle part of the shotpile — $K_\text{r} = 1.12 \div 1.2$, and in the upper part of the shotpile — $K_\text{r} = 1.3 \div 1.5$. The horizontal power of the buffer in place of the blasted rock mass should be taken within 10-15 m when the bench height is 10 m.

For technological schemes of ore and rocks crushing under the deep wedging-out space, the buffer power can be calculated by the formula:

$$N = W k_\text{rp} / \sin \alpha,$$

where $N$ is the capacity of “buffer”, $W$ is the line of opposition along the bench toe, m; $k_\text{rp}$ is the degree of rock fragmentation; $\alpha$ is the angle of bench slope degree.

One of the disadvantages of the buffer blasting is mixing gangue material with precious ores from the lying side of the ore body during excavation. This problem can be effectively solved with outlining and cutting off the ore body on the side of the footwall, using the trim blasting method.

In this case, it is not necessary to preserve the outline mass, as in the production of wall control at the final stage. For further rock working off, the effect of trim blastings should be used on the part of the lying side of the ore body. The main task of trim blasting in this case is to prevent the mixing of rocks on the side of the ore body during its excavation. A stable wall will not allow the rock to fall into the extractable space, that is excluded in standard working out of the last well rows at the ore-rock junction.

4. Conclusion

Thus, the quality management process of the mined ore with reducing losses and dilution is possible by means of using the special technological solutions for the preparation and mining operations.

The blast technology using the methods of buffer blasting and trim blast technology permit one to reduce losses and dilution during mining and to increase the quality of mined ore.

The economic effect of using the technological solution at complex structure deposits is expressed in reducing damages from losses and dilution. The effectiveness index of the technology is the minimum economic damage, which takes into account the amount of damage from loss and dilution of ore and is calculated by the formula

$$L_\text{i} \cdot S_\text{i} \cdot l \cdot \gamma_\text{o} + L_\text{d} \cdot S_\text{d} \cdot l \cdot \gamma_\text{r} \rightarrow \min,$$

where $L_\text{i}$ is the economic loss from the ore loss, ruble / ton; $L_\text{d}$ is the economic loss from dilution one thousand ton of ore, ruble / ton; $S_\text{i}$ is the area of wasted ore in the vertical section of the ore body, m$^2$; $S_\text{d}$ is the area of the admixed rock in the vertical section of the ore body, m$^2$; $l$ is the length of junction zones in the plan, m; $\gamma_\text{o}$, $\gamma_\text{r}$ is the unit specific gravity of ore and the admixed rock, t / m.

Optimization of losses, clogging and dilution indicators in the quarries design should be carried out according to the developed methodology, which systematically takes into account the mining and geological features of complex ore deposits, the dynamics of the working zone formation, the features of the formation of excavating units, the economic efficiency and reliability of design solutions.

References

[1] Tokarenko A V, Gulenkov E V 2013 Mining Journal (3) 76-77
[2] Argimbaev K R, Alexandrovich I V 2016 Research Journal of Applied Sciences 11(5) 240-244
[3] Isheyskiy V A, Yakubovskiy M M 2016 Mining Journal (12) 55-59
[4] Annexes of the Mining Draft Development of Hardrock Gold in the Eldorado Field using surface mining. 2003.
[5] Fomin S I, Semenov A S, Marinin M A, Shevelev V A, Komarov YU A 2014 Pat. 2524716 Russian Federation, MPK51 E21 C41/26. Surface Mining of Mineral Wealth Deposits Including Working out of Ore Bodies in Ore and Overburden Junction by means of stripping. Bull. №22
[6] Fomin S I, Ivanov V V 2016 International Journal of Pharmacy and Technology 8 (4) 27196-27207
[7] Fomin S I, TRAN Dinh Bao, VU Dinh Trong 2016 Advances in Mining and Tunnelling (ICAMT) (University of Industry HA NOI, VIET NAM)
[8] Zhang Y, Huang J, Yuan H 2011 Chinese Journal of Rock Mechanics and Engineering 30 (5) 967-973
[9] Kutuzov B N, Tokarenko A V 2013 Mining Journal (7) 57-59
[10] Fomin S I, 1998 Sb. Scientific papers of the National Mining Academy of Ukraine. Dnepropetrovsk 36-42.
[11] 1994 Methodological guidelines for the standardization, identification and recording of gold-bearing ore (sands) losses and dilution during mining. (Roskomdragmet, AO «Irgiridmet», Irkutsk)
[12] Kava P B 2013 Optimal Losses Verification of Mineral Wealth in Junction Space of Ore Bodies while Surface Method Development of Complex Deposits. Published Summary of Thesis PhD. (Saint-Peterburg) p 24