Increases in the volume of ore loss in ore pillars as the mine deepens

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Abstract. The article discusses the increase in ore loss in mining systems with natural maintenance pillars of the developed space, which cannot be extracted in conditions of high concentration of stress after development of reserves. The main directions of increasing the efficiency of traditional systems for the development of vein deposits are shown.

1 Introduction

Non-ferrous metal ores are characterized by a variety of mining and geological conditions, the extraction of which determines the use of various development systems with different technical and economic indicators [1,2].

To date, in attempts to increase extraction rates, some geotechnologies require additional material resources and labor resources, which casts doubt on the expediency of their application. The current situation in the mining industry is due to the imperfection of the applied development systems and the inability of the latter, taking into account the technical means used, to ensure the extraction of mineral raw materials at a competitive level.

When developing vein deposits of high value, various variants of the system with ore storage (with an ore body capacity of up to 2.0 m) and a sub-storey collapse, sublevel mining system, (with an ore body capacity of more than 2.0 m with sustained elements of occurrence) are used. Systems with a backfill due to the high complexity of the work and the imperfections of the available options have limited use, but due to the increase in the depth of development and the complication of mining and geological conditions, the scope of application of this system is expanding [3,4,5,6].

Thus, the study of a rational field of application of development systems of vein deposits, the development and widespread introduction of technological schemes without loss and dilution of ore is one of the important directions in the conditions of mountain pressures caused by an increase of depth in mining operations.

The work of the mines shows the irrationality of the development systems with the maintenance, supporting, of the developed space of valuable ores by the pillars due to the inability to work them out in conditions of high stress concentration formed after the release of the stored, blasted and hold in its place, ore. Here it is necessary to determine the size of the natural ore pillars left and the amount of ore loss in it, depending on specific conditions,

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variety of mining-geological, physico-mechanical factors, the parameters of the developed space determining the technical and economic indicators of the development systems.

2 Materials and methods

Various rationing methods are used to determine the loss of minerals during extraction [7]. Most of them are based on technical methods for determining standards – according to the size of the pillars, characteristic of the development systems used.

Existing calculation methods allow us to determine the dimensions, sizes, of inter-chamber pillars in almost any mining conditions.

So, for low-capacity and medium-capacity deposits, when the chambers are located along the stretch the VNIMI metodology can be used, based on the hypothesis of Turner Shevyakov.

The VNIMI methodology takes into account the weakening influence of the drifts carried out in the pillars and considers two cases: the central location of the block rising drift in the pillar (Figure 1a) and the flanking location (Figure 1b). In each case, the calculation is carried out in two stages, taking the larger of the two obtained by calculation as the final size of the drift.

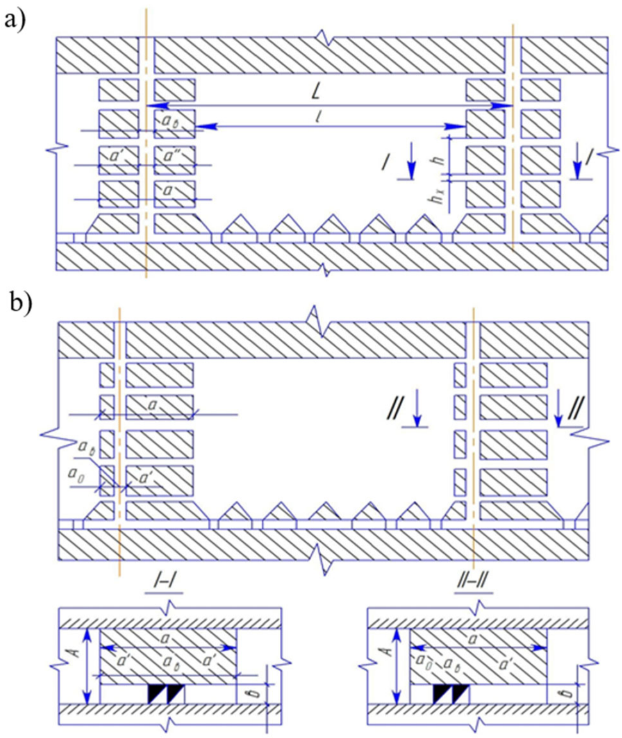

Fig. 1. Schemes for determining the calculated width of the pillars.

1. Determine the width of the "legs" of the pillar, the block raising and horizontal moves (if the latter are available, as, for example, when using development systems with a collapse from the store and with a sub-storey collapse), i.e., the width of isolated rectangular support pillars located on the long side of the uprising.

2. Determine the width of the inter-chamber pillar, taking into account its height in the stretch cross, while the calculation is carried out as for a solid ribbon pillar, and the influence of the rising drift and the horizontal moves are taken into account by the so-called priming coefficient.

With the central location of the rising drift, the calculation is carried out in the following order.

The width of the "legs" of the pillar is determined by the formula:

$$a' = q + \sqrt{q^2 + q(l + a_r)},\ m; \quad (1)$$

Where

$$q = \frac{\gamma H n K_o K_a h b}{[2000 K_s K_t \sigma_{pr}(h - h_m)]}, \quad (2)$$

n – the coefficient of extra strength, n=1,4–1,7;

h – the vertical distance between the horizontal moves (entering drifts to chamber), m;

b – moves (entering drifts to chamber) width, m;

σ_{pr} – the compressive strength of roof rocks, MPa.

K_o – a coefficient that takes into account the capacity of the overlying rocks, creating loads, pressure, on the pillars (at a ratio of B/N ≥ 0.8-1.0 –K_o = 1; at B / N < 0.8 – K_o = 0.7).

K_a – coefficient that takes into account the angle of incidence of the deposit, $K_a = \cos^2\alpha + V\sin^2\alpha$;

K_s – coefficient of structural weakening of the array, $K_s = 0{,}67 l_t^{0{,}52}$;

l_t – the distance between the trenches, m;

K_t – coefficient that takes into account the time of standing of the pillar, K_t = 1;

h_m –moves height, m;

a_r – width of the rising drift, m;

The total width of the pillar

$$a = 2a' + a_r\ . \quad (3)$$

Overload factor

$$K_o = ah/[2a'(h - h_m)]\ . \quad (4)$$

The total width of the pillar, taking into account its size (height) in the stretch cross (or, what is the same in this case, the span of chamber A), is determined if a/A<1$\left(K_f = \sqrt{\frac{a}{A}}\right)$ similar to the width of the ribbon pillar by the graphoanalytic method

$$a = lq_1/(K_f - q_1),\ m; \quad (5)$$

where

$$q_1 = \frac{\gamma H n K_o K_a K_n}{1000 K_s K_t \sigma_{pr}} \quad (6)$$

3 Results

So, in accordance with this methodology, an algorithm for a computer has been developed, calculations for various geomechanical conditions have been done and corresponding computer graphs have been constructed (Figure 2).

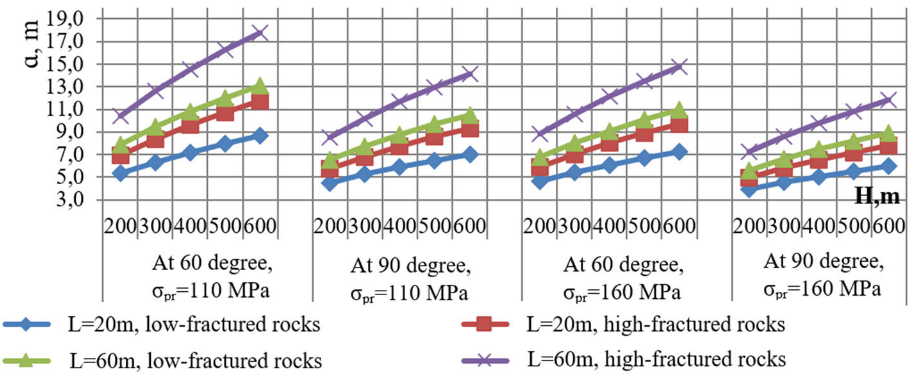

Fig. 2. Graphs of changes in the width of the pillar (a) depending on the depth of mining operations (H), the angle of incidence of the ore body (α), the length of the chamber (L_c) and fracturing of rocks within the compressive strength of rocks σ_{pr} = 110 MPa and σ_{pr} = 160 MPa.

It can be seen from the graphs that, depending on changes in the geomechanical conditions of the deposit, the stable width of the pillar varies in the ranges of 4.0 m ÷18 m. At the same time, an increase in the depth of mining operations (H) and fracturing of rocks, as well as a decrease in the length of the chamber (L_c), will lead to a significant increase in the width of the whole. The stable width of the pillar decreases with an increase in the angle of incidence of the ore body (α) and the compressive strength (σ_{pr},).

There are no completely reliable methods for calculating the ceilings of the chambers. According to the recommendations of M.I. Agoshkov, the ratio of the height of the horizontal ceiling to the span of the chamber's *h/A*, if the chambers are located along the strike, is assumed to be equal to: 0.2 - 0.3 – in favorable conditions of development, in very stable ores; 0.3 - 0.5 – for medium conditions, with stable ores and rocks with local attenuation; 0.5-0.7 – in unfavorable development conditions (Figure 3).

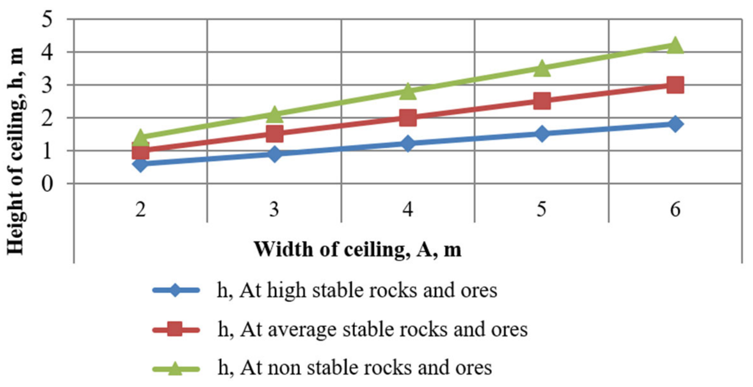

Fig. 3. The dependence of the height of the ceiling (h) on the width of the span (A) with a structural attenuation coefficient of K_s = 0.4, and a development period of up to 2 years.

The final size of the ceiling is determined taking into account the coefficient taking into account the time of standing of the pillar. For periods of standing up to 2, from 2 to 5 and more than 5 years, the value of this coefficient can be assumed to be equal to 1; 1.25 and 1.43, respectively, if the coefficient of structural weakening of $K_S \geq 0,4$, and equal to 1; 1.43 and 2, respectively.

The graphs show that an increase in the span width (ore extraction capacity), from 2 m to 6 m, leads to a corresponding increase in the ceiling height from 1.0 m to 3.0 m in medium-stable arrays and from 1.5 m to 4.2 m in unstable arrays.

The specific volume of ore losses in natural pillars under the mining system with the storage of ore with natural and artificial pillars from hardening mixtures is expressed in units/t.

$$P_{sp.loss} = \frac{\sum V_{ore.pillar}}{V_{bl}}, \quad (7)$$

where $\Sigma V_{ore.pillar}$ – the total volume of ore in pillars, it consists of the volumes of inerblock and interstory pillars, namely

$$\sum V_{ore.pillar} = V_{inb.p} + V_{ins.p}, \quad (8)$$

$V_{inb.p}$– the volume of interblock pillars, m^3;

$$V_{inb.p} = N_p * V_{o.p.p}\ , \quad (9)$$

N_p – the number of pillars in one rising drift with two cut-off slots

$$N_p = \frac{H_f}{h_p}, \quad (10)$$

H_f – floor height, m;

h_p – the distance between the axes of the running drift, m;

$$h_p = h + h_m\ , \quad (11)$$

h – the height of the pillar, m;

h_m – the height of the moves, m

The volume of one pair of pillars

$$V_{o.p.p} = h * a^1 * m * 2\ , \quad (12)$$

m – the capacity of the ore body, m;

a^1 – the width of the interblock pillar, m (determined by the VNIMI methodology, Figure 2).

The volumes of the interstory (above haulage drifts) pillars

$$V_{ins.p.} = h_{ins.p} * m * L_{ch} = \frac{B*sin\beta*m*L_{ch}}{\sin(\alpha+\beta)}\ , \quad (13)$$

where $h_{ins.p}$– height of the interstory pillars, m;

L_{ch}– the length of the cleaning chamber, m;

B – the distance between the axes of the ore access, m;

$$B = B_{ins.p} + B_o\ , \quad (14)$$

$B_{ins.p}$ – the width of the inter-floor drift, m;

B_o – width of ore access, m;

β – the angle of incidence of the ore taking hole, deg;

α – the angle of incidence of the ore body, deg.

Total ore reserves in the block, m^3;

$$V_{bl} = L_{bl} * H_f * m\ , \quad (15)$$

Where L_{bl} – the length of the block, m;

$$L_{bl} = L_{ch} + 2 * a^1 + a_{r.r}\ , \quad (16)$$

L_{ch}– length of the cleaning chamber, m;

$a_{r.r}$ – the width of the running rising drift, m.

Figure 4 shows graphs of changes in the volume of returned ore losses in the pillars of the block (section) constructed by the results of computer calculations according to the above methodology.

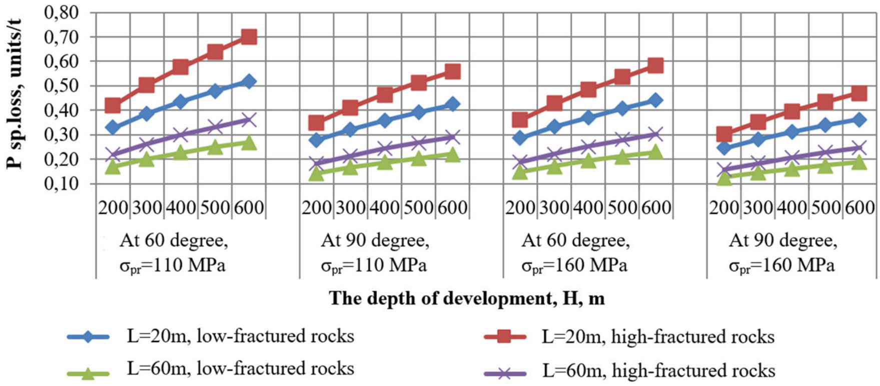

Fig. 4. Graphs of changes in the volume of ore losses depending on the depth of mining operations, fracturing of the massif, the angle of incidence of the ore body, the length of the block and the compressive strength of rocks, with mining systems with natural pillars.

From the graphs (Figure 4) it can be seen that the loss of ore in the drifts increases significantly depending on the increase in the depth of development and fracturing of the massif and it decreases with the increase in the angle of incidence of the ore body, the length of the excavation unit and the compressive strength of the massif.

The loss of ore in the pillar increases with an increase in the depth of development from 200m to 600m by an average of 20% and by 10% with an increase in the thickness of the array. With an increase in the angle of incidence of the ore body from 600 to 900 and the length of the excavation unit from 20m to 60m, the specific volumes of lost ore decreases to 10% and 14%, respectively. An increase in the compressive strength of rocks from 110 MPA to 160 MPa leads to a decrease in ore losses by an average of 3%.

4 Conclusion

In underground mining systems with natural maintenance of the developed space, the volume of loss in ore pillars increases with increasing depth of the mine and stress concentration. The scope of application of these systems is limited by the amount of reserves in the pillars, the extraction of which becomes either ineffective or even impossible without the use of special measures of protection.

Measures for occupational safety and loss reduction should be aimed at:

- creation of safe conditions for the personnel of the carrying out mining operations and reduction of ore losses to the level of systems with a backfill with a steady increase in rock pressures with a decrease in the depth of the mine;
- creation of new structures with artificial pillars from a hardening mixture to replace the natural ore pillars of traditional mining systems under high stresses of the mountain arrays, taking into account the possibility of using the ore-free zones of the massif as natural support pillars;
- reduction of ore extraction costs by applying the most advanced methods of managing arrays with combined types of backfilling materials;
- development of a methodology for determining the rational parameters of development systems with artificial solidifying mixtures and rational areas of their use.

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