OPTIMIZING PARAMETERS OF STOPES AND PILLARS FOR THE ZHDANOV DEPOSIT MINING

Introduction

The Zhdanov deposit occurs in the Pechenga area of the Murmansk Region [1–3] and holds one of Russia’s largest reserves of copper and nickel. Minerals are extracted by Severny Mine of the Kola Mining and Metallurgical Company. The mining project embraces 6 ore bodies: South-West, West, Central, East, South-East and South [4].

The South ore body occurs in the south-east of the Zhdanov deposit, is tabular and composed of mostly ordinary disseminated ore. The ore body is from 7 to 20 m thick, and its dip angle varies from 70° to 75° [5].

One of the accepted mining systems for the Zhdanov deposit is sublevel caving combined with stopes and pillars [6]. Within a level 60 m high, ore is extracted from stopes with temporal rib and level pillars. Inside a stope, the reserves are caved by sublevels with a height from 15 to 30 m [7]. Stability of the pillars and enclosing rock mass is ensured by efficient span of stopes and dimensions of pillars [8–11].

Intensive and deeper level mining results in worsening of geological and geotechnical conditions in the Zhdanov deposit. Thus, it is of concern to analyze stress state of rocks and to assess meticulously parameters of stable stopes and pillars.

Research methods

Stress state of rock mass around stopes was estimated in the numerical modeling. This method is widely used to estimate pillar stability and identify safe mining system parameters [12–16]. The present research was undertaken in terms of an isotropic rock mass in 2D finite element modeling.

Stability of the level and rib pillars was estimated using the constructed models of vertical and horizontal sections. The models are schematically shown in Figs. 1 and 2, including the modeling domain, stopes, pillars, mined-out void, geology and boundary conditions.

The boundary conditions were set in the models base on the data obtained in stress measurement by the method of stress relief with a few recent years [17].

Physical and mechanical properties of rocks are described in Table 1. The enclosing rock mass is strong with the minimum compressive strength $\sigma_c \approx 100 \text{ MPa}$ and minimum tensile strength $\sigma_t \approx 10 \text{ MPa}$.

Fig 1. Model schemes for vertical (a) and horizontal (b) sections

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The modeling produced stress field in rock mass around project rooms.

Results

At the first stage, stress state of level pillar between caving and stopping zones. Figure 2 shows the distribution of the major $\sigma_1$ and minor $\sigma_2$ principal stresses in the vertical section across the ore body strike and in the middle of the stope (See Figs. 2a and 2b, respectively).

As seen in Fig. 2a, the main concentrations of $\sigma_1$ are at the corners of the stope and under the stopping zone. In the level pillar, the stresses vary from 40 to 55 MPa. Analysis of the minor stress $\sigma_2$ (See Fig. 2b) reveals no considerable tensile stresses in the pillar or around the stope.

In rock mass around the stope and in the level pillar, all stresses are compressive and concentrate in the corner zones. The obtained results indicate stability of the level pillar, crown pillar, and stope walls.

At the next stage, the rib pillars were assessed. First, the variant proposed by the project agency with pillar width and stope span of 25 m was analyzed. Figure 3 presents distribution of $\sigma_1$ in the horizontal section (plan view) along the middle of the stopes.

The maximum values of stress in the pillars vary from 20 to 30 MPa, which is much below the strength of enclosing rocks.

Near the stopes on Level -260 m, a permanent opening is driven—a rock footwall drift which occurs in the concentration zone of the maximum stresses up to 50–55 MPa. Thus, the close-spaced location of stopes can impact stability of the rock footwall drift. Figure 4 shows an example of a damaged footwall drive in the influence zone of stoping.

Figure 5 shows the distribution of the minor stress $\sigma_2$ in the horizontal plane.

The minor stress analysis (Fig. 6) shows no tensile stress in the pillars between stopes K15 and K17 (pillar 15/17) as well as between K19 and K21 (pillar 19/21). The absolute values of tensile stresses in these pillars are nearby zero. The estimate of the pillar between stopes K17 and K19 (pillar 17/19) finds that the pillar is totally in the zone of tensile stresses with the values up to 4 MPa in the center.

This tension zone is connected with the ore body geometry. Direction of the major stresses in this zone is oriented at an angle relative to the ore body, which is conductive to tensions. The values of the tensile stress approach the ultimate tension strength of enclosing rock mass. Moreover, this area is heavily fractured. These facts implicate instability of the pillar given the tensile stresses arisen.

Safe dimension of pillar 17/19 along the ore body strike was determined in modeling a few alternatives with an increase in the pillar width by 5 m and re-arrangement of stopes K19 and K21. It was found that with a width of 45 m, pillar 17/19 is free from the tensile stresses, and, thus, is stable.

Aimed to improve mining efficiency, the authors modeled variants with the reduced width of pillars 15/17 and 19/21. The minor stress analysis showed no tensile stresses when pillars 15/17 and 19/21 were 20 and 25 m wide, respectively (See Fig. 6).

Table 1. Physical and mechanical properties of ore and enclosing rocks

<table>
<thead>
<tr>
<th>Ore and enclosing rocks</th>
<th>Density, t/m³</th>
<th>Poisson’s ratio</th>
<th>Elasticity modulus, GPa</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mineralized metasedimentary rocks</td>
<td>2.76</td>
<td>0.27</td>
<td>77</td>
</tr>
<tr>
<td>Disseminated ore (ore body)</td>
<td>2.94</td>
<td>0.32</td>
<td>71</td>
</tr>
<tr>
<td>Gabbro-diabase</td>
<td>2.97</td>
<td>0.31</td>
<td>86</td>
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<tr>
<td>Diabase</td>
<td>2.85</td>
<td>0.31</td>
<td>71</td>
</tr>
<tr>
<td>Pendentite</td>
<td>2.95</td>
<td>0.31</td>
<td>79</td>
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In this manner, the optimized sizes of pillars from the numerical modeling are: pillar 15/17—20 m; pillar 17/19—45 m; pillar 19/21—25 m.

**Conclusion**

The implemented research has found the rational parameters of mining the South-East ore body with stopes and pillars. The stopes and pillars keep stable when:

1. the level pillar height is 30 m;
2. the stope span along the strike is 25 m;
3. the rib pillar 15/17 width is 20 m;
4. the rib pillar 17/19 width is 45 m;
5. the rib pillar 19/21 width is 30 m.

Naturally, it is impossible to change the ore body geometry and the direction of the major stresses in rock mass. For this reason, towards mining safety, it is recommended to extract mineral reserves from pillars as soon as possible, to shorten life of the pillars thereby, and to arrange monitoring of the pillars.

**References**