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# EXAMINATION AND ANALYSIS OF ACTUAL STABILITY OF MINE WORKINGS AT THE YAKOVLEVSKY IRON ORE DEPOSIT

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## ABSTRACT

The Yakovlevsky iron ore deposit is one of the largest discovered deposits of high quality ore with the content of pure iron in the ore up to 70% and low content of harmful impurities (sulfur, phosphorus, etc.). The deposit is characterized by complex hydrogeological and mining conditions. The steep thick deposit is represented by (up to 50%) loose and semi-loose ores with the ultimate strength for uniaxial compression between 0.3 and 3 MPa and the presence of high-pressure aquifers. The paper considers the structural peculiarities of the ore deposit and enclosing rocks of the Yakovlevsky deposit of rich iron ores (RIO). Mine workings and interfaces stability observation data have been shown. The recommended parameters of fiberglass roof bolting for mine workings under the filling mass for the conditions of the Yakovlevsky deposit have been justified.

**Keywords:** structure, rock ore, working, breakout formation, fracturing, stability.

## 1. INTRODUCTION

The Yakovlevsky ore deposit is characterized by complex internal structure (Figure-1.) [1, 2, 3], the characteristic feature of which is the alternation of bands and layers of ore with various mineral composition and highly complex spatial geometry. Thus, ores of North-West strike with descent towards North-East at the angle of 45...75 ° occur along technological gate entry No. 1 (Figure-1, a). The ore is friable, with martite-hydro hematite composition, sometimes with interbeds of clay-like hydrogoethite ore. Overlaps of thin interlayers of inter-ore schists occur. The rock mass is divided by differently oriented cracks. Cross-heading 9 when viewed left to right (Figure-1, b) has been passed through the iron-biotide-martitequartzites of the North-West strike with descent in the North-East at the angle of 55-60°. In the range between 30.0 and 120.0 m, the working was made in the iron-biotide-martite loose and semi-loose chloritized and brecciated low strength ore. In the range between 45.0 and 50.0 m, between and 65.0 and 75.0 m, layers of fractured quartzitic schist were detected.

Thickness of ore deposits is subject to significant variations [4, 5]. Close to the bottom wall of the band of ferruginous quartzites, thickness of RIO deposit varies in the range between 20 and 30 m, in the middle part and the bottom wall of the ore-bearing band, RIO thickness typically increases to 100...200 m. At the Yakovlevsky deposit, it has been found that in addition to RIO, there are developed ores that stretch down to the depth of 300...500 m from the surface of the Precambrian basement, genetically related to the linear weathering crust. These ores form wedged tabular ore bodies. Sometimes they go to considerable depths without complete thinning tracked [6].

Within the covering rock cover, the clay-limestone thickness of carbon features substantially higher strength of limestone, compared to other rocks, and occurrence directly on RIO of the weathering crust. The distinctive feature of the carbon thickness structure is heterogeneity of its structure, and the presence of limestones of various types with interbeds and lenses of clays.

The ore body is characterized by alternation of various types of ores with distinct contact plots. Most often, two types of contacting ores are met, namely, iron-biotide-martite and martite-hydrohematite ore.

Studying the structural peculiarities of the ore-crystalline complex of rocks allowed identifying the system of bedding joints and the systems of shear fractures within the primary section. Bedding joints and interbed fractures are most developed on the site of primary working. By the results of mapping it has been found that intensity of bedding joints depends on schistosity of the rocks and the presence of silicate interbeds, the planes of which are typical gliding planes. Due to the determining the occurrence of banded quartzites in the bottom wall of the section, these systems of cracks will have the greatest influence on the rock mass stability. All crack systems have steep decline (β=60...86°).

Textural characteristics of RIO determine the strength, deformation ability, and values of mechanical properties of both individual samples and rock masses [7, 8] of ores. These circumstances must be taken into account when assigning calculated indicators for assessing the stress-strain state of rocks around excavations.

Analysis of the previous studies at the Yakovlevsky deposit shows [9, 10] that the most spread in the context of the residual genesis ore deposits are semi-loose and loose ores - 53.6%, sometimes up to 78%, the share of rock types is up to 22.5% and half-rock - about 21.4%. With that, rock ores form almost continuous crust in the top part of the deposit section. The Yakovlevsky field is characterized by a gradual replacement (top to bottom) of rock cemented strong ore varieties and loose ores, and in the bottom part of the open cut there are semi-loose and loose ores of the lowest strength. These types of ores at the Yakovlevsky deposit form huge rock masses that occupy the inside and the bottom wall part of the reservoir. Sometimes, rock masses of the weakest ores go directly under the overlying sediment rock. At the same

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time, within the weathering crust of the Yakovlevsky deposit (compared to other deposits of the Kursk magnetic anomaly (KMA)), significant amounts of remaining relatively fresh strong ferruginous quartzites are found. Such a selective nature of the process of weathering is associated with the tectonic conditions of this field development.

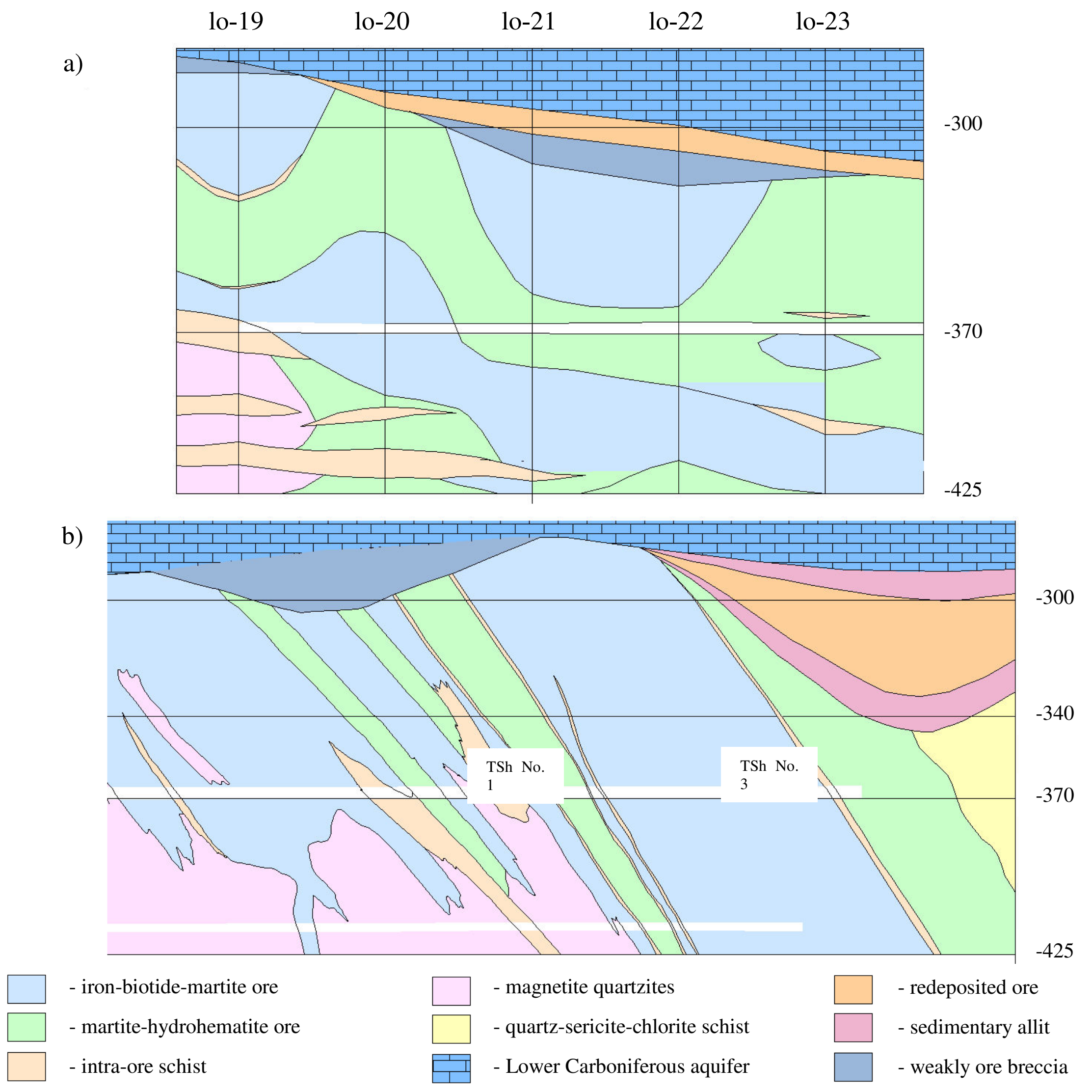


**Figure-1.** Geological open cut of the ore body: a) along the technological gateway No. 1; b) - along the lines of cross-cut No. 9.

## 2. METHODS

### 2.1 The subject of observation

Analyzing the graphical data and the information about the characteristics features of the structure and formation of rich iron ore of the Yakovlevsky deposit, several most characteristic unhomogeneities may be outlined: tectonic faults, contact of ores of various types (iron-biotide-martite and martite-hydrohematite ores), inclusion of mining waste (intra-ore schist, quartzite) into the ore mass [11].

These unhomogeneities have a significant impact in determining the stresses in intact ore mass, and during assessment of the stress-strain state of rocks around workings [12, 13, 14].

The purpose of the observations was establishing the nature of formation of natural equilibrium (collapse) arch around horizontal workings in the low strength ore mass with the presence of unhomogeneities [15].

The research was focused on the rush-in formations that occurred during the period of construction and operation of the mine workings located on horizons -425 m and -370 m of the Yakovlevsky deposit. Almost all the rush-ins occurred in the zones of contact of ores of different types or ores with mining waste. Mining wastes occur on both horizons, they are mainly ferruginous quartzites and layers of intra-ore slate.

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The geometric dimensions of rush-ins and their orientation relative to the workings were determined by an angle meter and a laser rangefinder. Due to the fact that the area of rush-in formation is a high-risk area, measurements were made from the point of the roof arch touching the contour of unbroken rock mass. The distance and the angle of the range finder were recorded. Next, with the use of trigonometric functions, the distance from the outer contour of the lining to the formed arch of natural balance was determined; if lining was absent in the area of rush-in formation, the distance was determined from imagined contour of the working. Geological characteristic of the containing ore mass was accepted according to the data from the geological service of the mine deposit. By the results of the measurement, the layout of rush-in formation was defined.

One of adverse workings at the -370 m horizon in terms of the number of rush-ins is panel crosscut 7. In the interval between SP 769+5.0 m (survey peg (SP)) to SP 769+10.0 m, the working was made through intra-ore schists. Rocks are of medium strength, with medium fracturing. In the interval between SP 769+10.0 m and SP 769+85.0 m, the working was made through silica quartzites, and quartzitic schists. Rocks are separated by differently oriented tectonic cracks. The cavities of the cracks are made of loose and clay-like ore, occasionally of calcite. The distance between the cracks is 0.1 to 0.5 m. At the points of crossing, the cracks are prone to rush-in formation. In the range between SP 769+85.0 m and SP 769+100.0 m, the working was made in the iron-biotide-martite loose and semi-loose chloritized and brecciated low strength ore. In the range between SP 769+85.0 m and SP 769+100.0 m, the working was made in the martite-hydrohematite chloritized, carbonized and sometimes brecciated low strength ore. Overlaps of thin interlayers of inter-ore schists are possible. The rock mass is divided by differently oriented tectonic cracks. The distance between the cracks is 0.1 to 0.5 m. In the range between SP 769+85.0 m and SP 769+100.0 m, the working was made in the iron-biotide-martite loose and semi-loose chloritized and brecciated low strength ore. In the range between SP 769+180.0 m and SP 769+210.0 m, the working was made in chloritized, carbonized martite-hydrohematite and hydrohematite ores. The ores are partly breccicated and crumpled into folds. The rock mass is divided by differently oriented tectonic cracks. The distance between the cracks is 0.1 to 0.5 m. In the range between SP 769+85.0 m and SP 769+100.0 m, the working was made in dense iron-biotide-martite chloritized and carbonated medium and low strength ores. At the points of crossing, the cracks are prone to rush-in formation. In the interval between SP 769+225.0 m and SP 769+235.0 m, workings were made through allits and ferrallites. In the interval between SP 769+235.0 m and SP 769+250.0 m, workings were made through redeposited ores. The rock mass is divided by differently oriented tectonic cracks. The distance between the cracks is 0.1 to 0.5 m. The strength of ores depends on the composition of breccia and cement. For horizon -425 mm, such working will be PSG 4 (panel supply gate). The working within the first 13.0 m (right to left) was made through strong stable thin-layered iron-biotide-martite quartzite. The rocks are of the North-Western strike with descent toward the North-East at the angle of 60-70°. The rock mass is divided by differently oriented cracks up to 0.5 m thick. The distance between the cracks is 0.1 to 0.5 m. Cracks are made by loose martite ore, which is very unstable. The working has been made along the strike of the rock. Further, in the range between 13.0 and +50.0 m, it was made though loose and semi-loose iron-biotide-martite folding ore.

### 2.2 Examples of fixed rush-ins

The following is the description of several rush-ins both for horizon -370 m and -425. All these rush-ins occurred along the workings track in the vicinity of, or directly at the locations of ore mass unhomogeneities.

Panel crosscut No. 7, horizon -370 m (Figure-2).

The working has been made across the stretch of the ore body. The rush-ins occurred in the interval between SP 709 +35.8 m and +46.5 m, the volume of the rush-in along the roof of the working was 60 $m^3$. The maximum height of the roof arch reaches 3 m, the size of the rush-in in the plane reaches 10.7 m long and approximately 4.5 m wide.

The rock mass is divided by differently oriented tectonic cracks, is unstable, the strength coefficient is $f \geq 2$. The working has been made in loose iron-biotide-martite ore. The fractures have the North-West orientation with descent towards North-East, also intersecting with the North-East strike with descent towards North-West at the angle of 70°. The working with cross-section $S \approx 19.8$ $m^2$ at the site of the rush-in has been secured with three-tier collapsible timbering KMP-A3 (metal arched three-tier collapsible timbering) with mesh reinforcement. The rush-in is due to the presence of tectonic dislocations along the working of distinct system, which is evidenced by the presence of large size pieces of ore in the roof and the shape of the rush-in elongated along its length. The reasons that promote formation of the rush-in are significant difference in the design cross-section of the working, poor quality of backfilling the space behind the lining.

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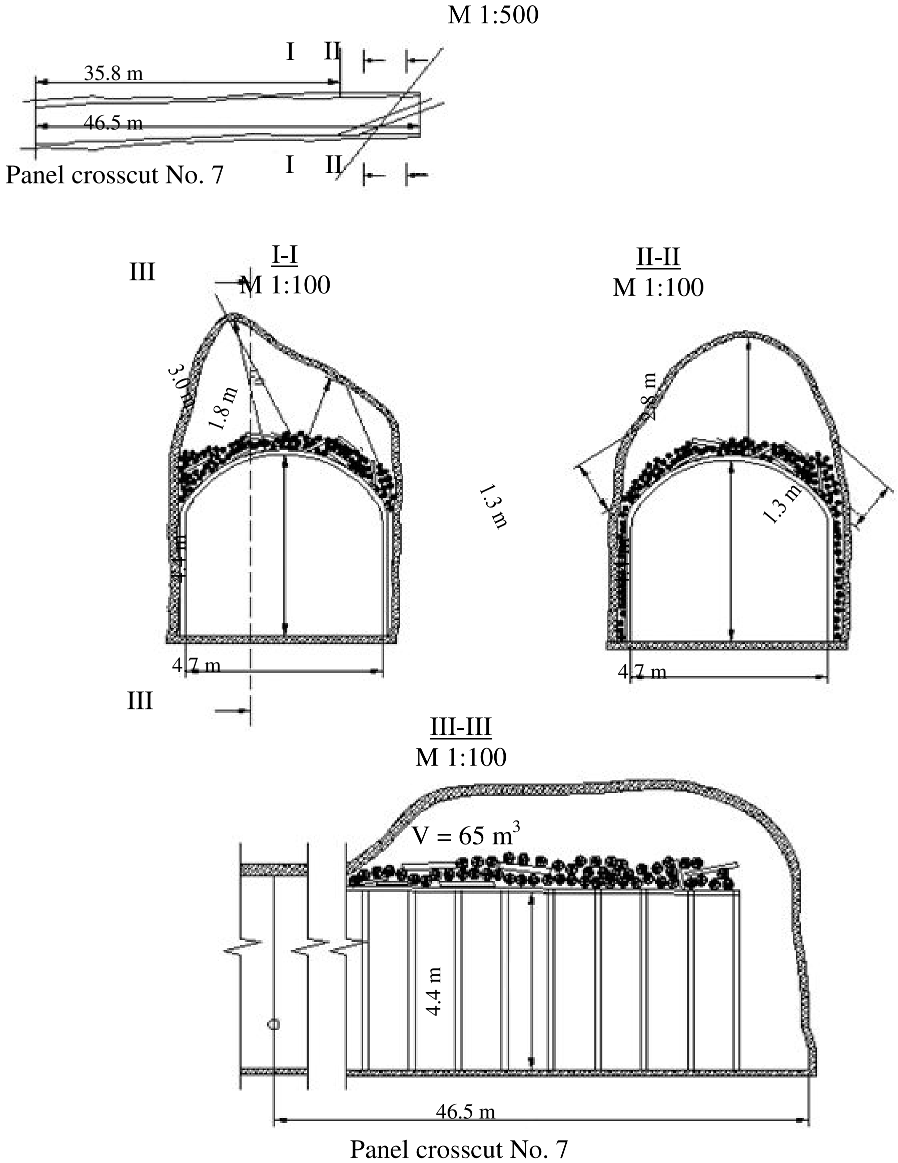


**Figure-2.** Scheme of the rush-in in the panel crosscut No. 7, horizon -370 m.

The photo (Figure-3) shows the view of an emergency working from the side of its stable part.

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**Figure-3.** Rush-in and destruction of lining KMP-A3 in the working.

**2.2.1 Technological gateway No. 1 (between panel cross-section No. 7 and the western ventilation and backfilling crosscut), horizon -370 m.**

A rush-in formation occurred during drilling of technological gateway No. 1 in horizon -370 m in the range between SP 815+21.3 m and SP 815+38.8 m. The volume of the rush-in was about 250 $m^3$, since the rush-in occurred from the roof and sides of the working, from the side of the hanging and bottom wall. The rush-in formation is due to opening of martite ores contact with hydrohematite ores, and closeness of the working to the contact of martite ores with quartzites of the bottom wall. The contacts include fractures, therefore the structural links in the ore mass are weakened. Martite ores $f<1$ have low strength, therefore they are very unstable. Hydrohematite ores with the strength of $f=1...3$ are unstable. Besides, the reason of the rush-in was the absence of lining in the working in this interval. The maximum height of the roof arch of 2.0 m may be traced almost throughout the entire rush-in, and sharply decreases on the border. The size of the rush-in in the plane is 17.5 m long and approximately 5 m wide.

**2.2.2 Ventilation and stowage gate entry of the bottom wall, horizon -370 m.**

When drilling the ventilation and stowage gate entry of bottom wall at intervals from SP 596-1.4 m to SP 596 +29 m, a rush-in occurred from the sides and roof of the working equal to 150 $m^3$.

The working was made through the area of tectonic dislocations represented by intersecting cracks of the North-West and the ex-meridian strike. Most likely, this was the main reason for the rush-in, since the uneven ore contour formed in the roof of the working coincides with the intersection points of the main cracks. The area of tectonic dislocations is composed of loose and boulder breccia of weathered mineralized quartzite. The rock has low strength $f=2...4$ and is unstable. The area of the working has been reinforced with arched support KMP-A3. The maximum height of the roof arch is 3.1 m, the length of the rush-in reaches 28 m. The length of the tectonic dislocations zone is comparable with the length of the rush-in, and varies in the range between 27 and 30 m.

**2.2.3 Hanging wall gate entry No. 3, horizon -425 m.**

A rush-in occurred from the roof and the right side of the working in the intervals between SP 969+29.2 m and SP 969+32.7 m. The volume of the rush-in was 34 $m^3$. The area of the working has been reinforced with arched support KMP-A3. The rush-in occurred after blasting the next stope due to the opening the contact of the iron-biotide-martiteores with hydrohematite ores. The ores have low strength f<1, and are very unstable. The reasons contributing to the rush-in were poor backfilling the space behind the lining and the absence of additional lining frames in the face zone. It should also be noted that after a number of stopes and installation of two support arches, the works at this site were stopped and resumed only after a month.

**2.2.4 Haulage crosscut No. 10, horizon -425 m.**

The rush-in occurred in the interval between SP 746 +23.4 m and SP 746 + 28.5 m from the left side and the roof of the working, its volume was 60 $m^3$. The rush-in was due to opening the tectonic fault and flooding of the rock mass. The tectonic fault is represented by thinning of the sercite-chlorite schists on the right side. The schists can be traced along the roof until the left side, and protrude out on it at the height of 2 m. The working was made in loose martite ore with low strength f≤2...4. The working face of the working is represented by water-encroached hydrohematiteore, the rock mass is unstable.

**2.2.5 Haulage crosscut No. 7, horizon -425 m.**

From the start to + 70.0 m, crosscut No. 7 was made through medium thin-banded hematite quartzites with inclusions of loose iron-biotide ore. The rocks are of the North-West strike, with descent towards North-East at the angle of 55...65°. In the interval between 70.0 m and 80.0 m, from the beginning, chloritized, brecciated strong martite ore is present. In the interval between 80.0 m and 105.0 m, weathered, sometimes mineralized, fractured, hematite quartzite with interlayers of semi-loose martite ore are observed. In the interval between 105.0 m and 120.0 m, from the beginning of the working, strong chloritized, brecciated martite ore is present. In the interval between 120.0 m and 130.0 m, weathered wide-band silicate quartzite is found. In the interval between 130.0 m and 145.0 m - strong chloritized, brecciated martite ore is present. In the interval between 145.0 m and 170.0 m - weathered, chloritized, fractured silicate quartzite is found. In the interval between 105.0 m and 120.0 m, from the beginning of working, interlaying of semi-loose and loose hydrohematite-martite ore and strong chloritized and carbonatized ore is found. Next, a powerful bundle of intensively weathered quartz-sercite thinly bedded schists is expected.

In the interval between SP 713 +11.0 m and SP 713 +13.8 m, a rush-in formation occurred on the left side and the roof of the working. The volume of the rush-in was 60 $m^3$. Rush-in formation is mainly due to the complex mining and geological conditions and flooding the rock mass with water. For assessing the flooding, draining wells were drilled from the working, which ensured inflow of 18 $m^3$. The rock mass is unstable, represented by loose iron-biotide ore with low strength f<2. It should also be noted that the face of the working is divided by a series of differently oriented cracks. The maximum height of the roof arch is 6.5 m, the length of the rush-in reaches 2.5 m.

**2.2.6 Haulage crosscut No. 7, horizon -425 m.**

In the interval between SP 584 +42.0 m and SP 584 +45.5 m, a rush-in formation occurred in the roof and the sides of the working. The volume of the rush-in was 100 $m^3$. The area of the working has been reinforced with arched support KMP-A3.

The rush-in formation occurred after opening the zone of tectonic dislocations represented by the intersection of cracks of the North-West and ex-meridian strike. The rock mass is composed of loose sulphidized ore and boulder breccia of mineralized quartzite. The rock has low strength f=2...4, is unstable and prone to rush-in formation. The maximum height of the roof arch is 7 m, the length of the rush-in reaches 3.5 m.

**2.2.7 Prospect entry No. 4, horizon -425 m.**

When drilling the prospect entry, in the intervals between SP 732 +19.0 m and SP 732 +23.5 m, a rush-in formation occurred on the left side and the roof of the working equal to 60 $m^3$.

The working was made through the zone of tectonic dislocations represented by intersecting cracks of the North-West strike. Most likely, this was the main reason for the rush-in formation, since when opening the tectonic dislocation in the left side of the working, the zone of weakening was formed. The maximum height of the roof arch is 5.5 m, the length of the rush-in reaches 4.5 m, the width is 6.0 m. The rock mass is unstable, it is presented by loose, watered iron-biotide-martite ore with low strength f<2...4.

**3. RESULTS**

The main quantitative data about the detected and examined rush-ins are shown in Table-1.

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**Table-1.** General characteristic of rush-in formations.

| No. | Name of working | Type of lining (Sl, $m^2$) | Rock mass characteristic | The section of the rush-it | Parameters of the rush-in | | |
|---|---|---|---|---|---|---|---|
| | | | | | Length, m | Width, m | Height, m |
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
| Horizon -370 m | | | | | | | |
| 1 | Panel crosscut No. 7 | Arched support KMP-A3 | Tectonic dislocations, iron-biotide-martite ore, *f*≤2 | SP 709 + (35.8÷46.5) m | 10.7 | 4.5 | 3 |
| 2 | Technological gate entry No. 1 | Without lining | Contact of martite ores with hydrohematite ores, fractures of iron-biotide-martite ore, *f*≤1 | SP 815 + (21.3÷38.8) m | 17.5 | 5 | 2 |
| 3 | Western ventilation and backfilling crosscut | Without lining | Fractured sirica chlorite schist, *f*=2 | SP 750 + (34.2÷37.5) | 6.3 | 4.8 | 4 |
| 4 | Ventilation and stowage gate entry of the bottom wall | Arched support KMP-A3 | Loose breccia of weathered mineralized quartzite, the zone of tectonic dislocations, *f*≤4 | SP 596-1.4 m SP 596 +29 m | 30.4 | 6.1 | 3.1 |
| 5 | Ventilation and stowage gate entry of the bottom wall | Arched support KMP-A3 | Loose martite ore with tectonic dislocations, *f*≤4 | SP 504 + (12.3÷37.7) m | 25.4 | 5.8 | 0.6 |
| 6 | Central technological crosscut | Arched support KMP-A3 | Contact of martite ores with hydrohematite ores, *f*≤1 | SP 990-21m SP 990-13m | 8.0 | 5.3 | 3.5 |
| Horizon -425 m | | | | | | | |
| 1 | Hanging wall gate entry No. 3 | Arched support KMP-A3 | Contact between iron-biotide-martite ore and hydrohematite ore *f*≤1, contact | SP 969 + (29.2÷32.7) m | 3.5 | 5.8 | 1.0 |
| 2 | Haulage crosscut No. 10 | Arched support KMP-A3 | Contact, thinning of sercite-chlorite schists, iron-biotide-martite ore, *f*≤4 | SP 746 + (23.4÷28.5) m | 5.1 | 5.5 | 3.0 |
| 3 | Haulage crosscut No. 7 | Arched support KMP-A3 | Tectonic dislocations, iron-biotide-martite ore, *f*<2 | SP 713 + (11.0÷13.8) | 2.5 | 4.8 | 6.5 |
| 4 | Haulage crosscut No. 7 | Arched support KMP-A3 | Contact, sulphidized ore and boulder breccia of mineralized quartzite *f*≤4 | SP 584 + (42.0÷45.5) | 3.5 | 5.1 | 7.0 |
| 5 | Prospect entry No. 4 | Arched support KMP-A3 | Loose martite ore with tectonic dislocations, *f*≤4 | SP 732 + (19.0÷23.5) m | 4.5 | 6.0 | 5.5 |

## 4. DISCUSSIONS

The practice of drilling mining workings in ore body showed that stability of the ore mass is non-homogeneous when it is crossed along the strike and across the strike [17, 18, 20]. Table 2 shows an example of quantitative assessment of rush-in formation when drilling workings through ore blocks and horizons, across the stretch and along the stretch. The ore mass stability assessment criterion was the coefficient equal to the ratio of the total linear length of the rush-ins to the length of the drilled working in meters. The coefficients were calculated for individual workings, for individual blocks and the entire deposit as the weighted average for the total length of the workings. The calculations have shown that in the cross-cut workings, the coefficient of rush-in formation ($C_{rif.}$) varied between 0.04 and 0.10, the average coefficient for the mine amounted to 0.04. In gate way workings (along the strike), it was 0.04 to 0.20, the average one was 0.11.

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**Table-2.** Intensity of rush-in formation in workings along the strike and across the strike.

| Working | Horizon | Working strike | The total length of rush-in formation, m | Length of workings, m | Linear coefficient of rush-in formations |
|---|---|---|---|---|---|
| Block 6 | | | | | |
| Clean. stope 8 | -370 | Across | 8 | 260 | 0.03 |
| Clean. stope 4 | -370 | Across | 1 | 260 | 0.00 |
| Clean. stope 12 | -370 | Across | 7 | 260 | 0.03 |
| Clean. stope 16 | -370 | Across | 7 | 240 | 0.03 |
| Pan. crosscut 7 | -370 | Across | 12.5 | 320 | 0.04 |
| Weighted average for length of workings through the block: | | | | 1,580 | 0.03 |
| Technol. gate entry 1 | -370 | Along the strike | 30 | 440 | 0.07 |
| Technol. gate entry 3 | -370 | Along the strike | 5 | 440 | 0.01 |
| Weighted average for length of workings through the block: | | | | 880 | 0.04 |
| Block 5 | | | | | |
| Pan. crosscut 3 | -370 | Across | 12 | 240 | 0.05 |
| Pan. crosscut 4 | -370 | Across | 10 | 220 | 0.05 |
| Weighted average for length of workings through the block: | | | | 460 | 0.05 |
| Clean. stope 4 | -370 | Along the strike | 33 | 180 | 0.18 |
| Clean. stope 5 | -370 | Along the strike | 30 | 130 | 0.23 |
| Weighted average for length of workings through the block: | | | | 310 | 0.20 |
| Block 1 | | | | | |
| CTO | -370 | Across | 10 | 300 | 0.03 |
| Weighted average for length of workings through the block: | | | | 300 | 0.03 |
| Across gate entry 29 | | Along the strike | 5 | 100 | 0.05 |
| Across gate entry 25 | | Along the strike | 17.5 | 100 | 0.18 |
| Weighted average for length of workings through the block: | | | | 200 | 0.11 |
| Block 4-2 | | | | | |
| VSO | -415 | Across | 1 | 50 | 0.02 |
| VSO-28 | -415 | Across | 15 | 55 | 0.27 |
| VSO-30 | -415 | Across | 10 | 55 | 0.18 |
| VDO | -415 | Across | 1 | 100 | 0.01 |
| Weighted average for length of workings through the block: | | | | 260 | 0.10 |
| Block 4-2 | | | | | |
| Experimental working | -415 | Along the strike | 50 | 340 | 0.15 |
| PSG-4 | -415 | Along the strike | 35 | 340 | 0.10 |
| Slice drift 1 | -415 | Along the strike | 17.5 | 80 | 0.22 |
| Weighted average for length of workings through the block: | | | | 760 | 0.13 |
| Block 4-2 | | | | | |
| Rollback crosscut 2 | -425 | Across | 44 | 220 | 0.20 |
| Block 1 | | | | | |
| Rollback crosscut 1 | -425 | Across | 4 | 200 | 0.02 |
| **Total for the mine:** | | Along the strike | | 2,440 | 0.11 |
| | | Across | | 3,440 | 0.04 |

## 5. CONCLUSIONS

Thus, one can make a conclusion about a higher stability of the ore mass in the workings made across the strike, since the likelihood of complications of the mining and geological conditions during drilling is almost 3 times lower than those when workings are made along the strike.

As is well known, resistance of the rock mass is determined by its stress-strain state (SSS) and geological factors (composition, structure, texture, fracturing, etc) [16, 18, 19]. SSS is determined by the ratio of the main compression forces acting across and along the strike of the ore body. Tabular, steeply descending iron ore deposits (Kazakhstan, Kryvbas) are characterized the domination of the main compressive forces that act across the stretch over the forces that act along the stretch 2-4 times, which results in the pressure in the gate entries. At the Yakovlevsky deposit, such domination of the pressure across the stretch has not been identified during the study [21].

The main factor that actually determines the stability of the ore mass during drilling is the geological, namely: the presence of layer-by-layer fracturing in the ore; almost missing or weak structural bonds between thin beds of rock in semi-loose and loose rich ores; the presence of inclusions or ore waste in the ore mass (intra-ore schists and quartzite); and the average angle of striature descent of 60°.

The influence of these factors on the state of the rock mass during excavation of workings across the stretch is as follows: at the intersection of ore layers with weak structural bonds, in case of favorable descent angle (60°), in the sides of the working the layers work for compaction, rush-ins mainly occur in the face, from the side of the hanging wall. In this case, the size of exposure is determined by the width of the working. The influence on the state of the rock mass in case of drilling working along the strike is as follows: in case of such intersection of ores, the layers in the side and partly in the roof, especially from the side of the hanging wall, do not work for compression, resulting in the rush-in formation. In this case the size of the exposure is determined by the length of the working.

The results of the studies should serve in the future as an experimental basis for choosing a geomechanical model of ore mass destruction and substantiation of the loads on lining supports in workings.

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