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Dynamic rock pressure manifestation: case study

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Abstract. The development of the vein gold deposits in Russia results in the growing output of the underground ore extraction. The deposits' mining and geological conditions are aggravated by the increase of the mining depth (over 1,000 m) that causes a rise in the rock pressure manifested both in a static and dynamic form. This in turn leads to abrupt destruction of the rock bodies, which complicates the mining process and increases the production costs. In this connection, the federal code of field development practice requires research on the rock body's geo-mechanical state, and the corresponding geo-dynamic zoning. However, the practice shows that it is not always possible to detect the high-stress zones hazardous in terms of dynamic rock pressure manifestation [1]. The paper describes the study of the rock body's geo-mechanical state in the zone of the rock discharge from a raise at the Irokinda gold deposit. The study has defined the conditions under which the rock stress exceeds the alarm pressure level, as well as the additional factors causing a rise in the rock body stress on the workings' contour. The consideration of the above factors significantly enhances the validity of the geo-dynamic zoning prediction for the mine field rocks.

1. Introduction

The Irokinda gold deposit is represented by relatively thin inclined quartz veins occurring in the cryolite-zone conditions. The deposit is developed in sections on a few veins, the mined ore being transported to the gold-extracting factory. The deep mining is characterized by changes in the temperature mode and in the rock body natural stress. The vein's ore bodies are developed in complicated geological conditions requiring continuous geo-mechanical monitoring and geodynamic zoning of the rock body, especially on the lower level with the permafrost rocks outcrop. As an example, a study of the dynamic rock pressure manifestation case is described. The study has been conducted for the rock pressure manifestation when advancing raise No. 3 of the 890 m level (R-3/890) in the ore body of vein No. 3.

2. Materials and methods

The mining on vein No. 3 is performed on the levels of 990.940 and 890 m. The opening-up of the 890 m level is implemented by moving down the level reserves, while its preparation for stoping is implemented by advancing the drift and the raises.

Raise No. 3/890 (R 3/890) was a branch of drift No.2, 39 m advanced at the moment of the rock discharge. On the right side of the raise, three meters from the face front, a discharge of the rock mass in the form of thin rock plates had been registered, the discharge height being equal to that of the raise (Figure 1). This dynamic pressure manifestation had been preceded by rock crackling in the face body.

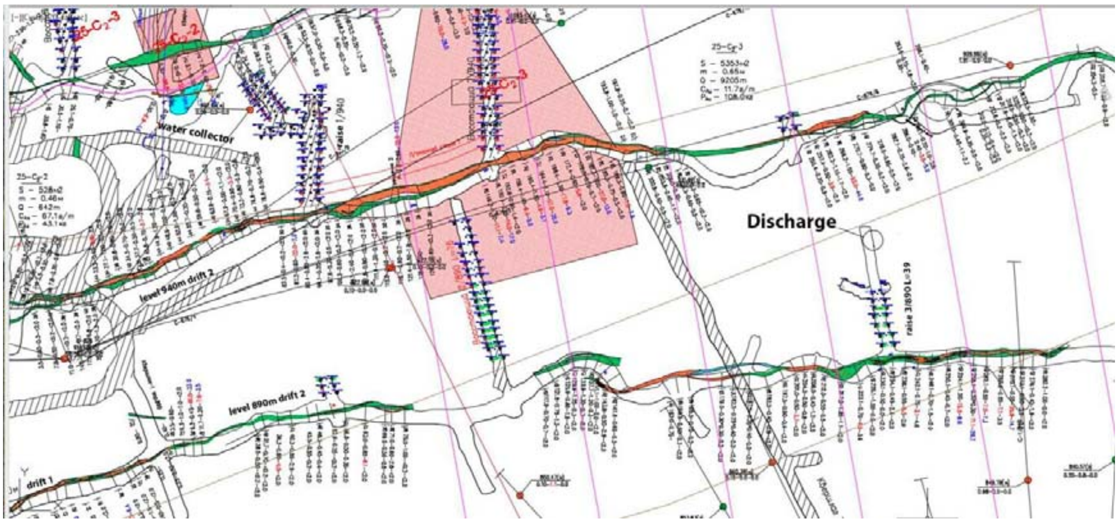

Figure 1. R-3/890 location.

On the other sections of the target levels' drift field, no cases of rock pressure manifestation had been registered.

The aim of the research was geo-dynamic zoning of the shaft levels' rock body of vein No. 3.

The shaft and raise deads are represented by different-composition gneiss and beresites. The vein is composed of fractured quartz with sulfide intermixture of 0.2 to 0.5% (pyrite, galenite). The quartz fractures are mostly sub-parallel to the rock body incline. There are deads' xenolites within the quartz vein. The vein has a lens-like structure, its thickness varying from 0.2 to 1.0 m in the bulges. The inclination angles vary from 35° to 45°. In immediate proximity to the ore body, the rocks are schistose. The closer the rocks to the vein contact, the higher the schistosity degree is. The schistosity zone contains fine-grain, thin-shistose rocks in the form of a chloritizated and graphitized clay-rubble material (Figure 2).

The research has used 'Methodological recommendations on evaluating burst risk of the ore- and non-metallic deposits' [1].

The class of the rock outcrop stability has been defined by a complex method integrating the rock physical-mechanical properties (PMP), tectonic state, fracturing intensity, as well as the roof relief and the temperature mode [2, 3]. The PMP of the rock samples have been studied at the Geo-mechanical and Physical Laboratory, INRTU in correspondence with the RF standards for rock testing.

The measurement of the rocks' natural stress has been done by a fissured-discharge method developed by the Mining Institute of the Ural Branch of Russian Academy of Sciences (MIUB, RAS) [4].

In order to define the rock body technogenic stress, a finite-element modeling method has been used. The method has been implemented with a FEM software complex developed by MIUB, RAS [5].

Figure 2. Rock body along the shaft 890 of vein No. 3.

The burst risk prediction has been conducted by a core-disking method, the basic method meeting the requirements of the above-mentioned methodological recommendations.

3. Research results and analysis

The research on the physical-mechanical rock properties has shown that the rocks have an average density of 2.8 t/m^3 and are classifies as hard rocks. The coefficient of hardness (by M.M. Protodjakonov) is variable, on average being 10. The ultimate compression strength is 115 MPa in a dry state, and 105.6 MPa, in a humid state; the ultimate tensile strength being 15.84 and 13.84 correspondingly. The angle of the rock internal friction is 34º. The rock adhesion is 30.23 MPa in a dry state, and 27.5 MPa, in a humid state. The target rocks have high elastic properties, the modulus of elasticity being 62.96 GPa, and the Poisson coefficient, 0.25.

The burst risk has been calculated by the G.N. Kuznetsov criterion. Rocks are brittle-fractured if:

$$K_{br} = \frac{\sigma_c}{\sigma_t} > 6 \tag{1}$$

where K_{br} is brittleness index; σ_c is uniaxial ultimate compression strength; and σ_t is uniaxial ultimate tensile strength, MPa.

The above calculation shows that the rocks of vein No.3 of the Irokinda gold deposit are in general prone to brittle fracturing under load. Potential burst-prone rocks are: quartz, beresites and gneiss. The average coefficient of brittleness for the vein is 8.5. The burst risk prediction has been made based on the analysis of the disk forming for the core 17 of the rock-body lower levels' wells. The analysis shows that there are no discs of 1-5 mm registered; therefore the workings of the shaft field can be classified as "no-risk" in terms of their proneness to rock burst.

Tensile breaches of the rock body are not connected with the first- and second-order tectonics and have a local character. The fracture system is discontinuous, the shape of the structure blocks being prismatic, rectangular and trapezoid. The number of the fractures for one running meter of the rock outcrop varies from 5 to 15 depending on the chosen interval, the structure weakening index being 0.4. The fractures are mostly open and breakage-filled.

The workings' stability is reduced due to the schistosity and graphitization zones in the ore-bearing capels, as well as to the fractures in the ore and ore-bearing rocks. The roof relief on the vein incline has a relatively even character, while on the vein strike it changes but not as much as to influence the roof stability. The roof is represented by the monolith metamorphic deads (as a rule, granite-gneiss) with a lateral layer orientation in relation to the ore-zone axial plane. Toward the ore body center, the deads gradually change into the modified rocks of a beresite composition. The side- and roof rocks are of a medium and unstable class.

The actual measurements have been done at a gage station of the 890 level situated at a depth of 410 m. The results of the natural measurements show that the vertical stress value (σ) is –11.6 MPa, the lateral stress value (σ_l) is –17.5 MPa, and the transverse stress value (σ_t) is –27.3 MPa, which can be expressed as:

$$\sigma = -\gamma H; \sigma_l = -1.5 \cdot \gamma H; \sigma_t = -2.4\gamma H \quad (2)$$

The results show that the transverse stress has a maximal value that is 2.4 times the one of the vertical stress. The calculation shows that the gravitational component of the lateral stress is negligible, being –4.4 MPa. Hence, the transverse tectonic value is –22.9 MPa, and the lateral one, –13.1 MPa. This can be explained by the fact that the rock body is situated in the syncline area (Figure 3).

Figure 3. Location of R-3/890 vertical exit point.

Taking into account the fact that the laboratory tests of the sample have shown the average value of the ultimate compression strength of –105.6 MPa and of the ultimate tensile strength, 13.8 MPa, the following allowed stress values can be accepted for the lower levels (vein 3) conditions: compression stress, -31.3 MPa, and tensile stress, 4.1 MPa.

The mathematical modeling has shown that the technogenic stress values in the workings of the 890 m level tend to be higher than the allowed values (Figure 4).

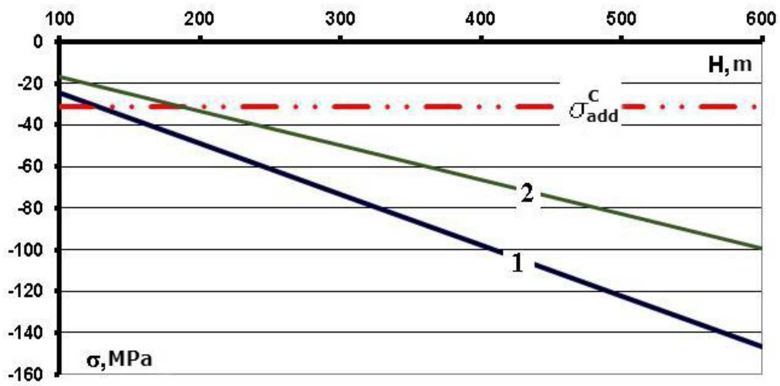

Figure 4. Technogenic stress in the shafts (the mining influence zone): 1 – haulage drifts, 2 – ventilation drifts.

The visual inspection of the workings of the 890 m level has shown that the rocks on the haulage drift do not withstand the stress and break along the fractures and the yielding fracturing zone (Figure 5).

Figure 5. Disintegration of the drift-side rocks along the fractures and graphitized schistosity zone.

When predicting the burst risk class of the rocks of the 890 m level, the allowed stress values are:

$$\sigma^c_{add} = 0{,}8\sigma^s_c \quad (3)$$

where σ_c^s is ultimate compression strength for the sample rocks, MPa; σ^c_{add} is allowed compression stress, MPa [1].

For the rocks of the 890 m level, the allowed stress value is –84.5 MPa. Thus, the stress value in the drifts at a depth of 410 m is higher than the allowed value.

4. Conclusion

In the conditions of brittle hard rocks and high stress, the rock body is of 'burst-risk' class, which has been confirmed by the manifestation of the rock pressure in the form of the rock discharge from the side R-3/890. In the above case, the structure of the raise rock body changed (compared to that of the drift), the vein blew out, the graphitized schistosity zones disappeared, and the rocks with a streaky bearing-strain structure became less fractured (Figure 6), which led to the accumulation of energy and, with the stress having exceeded the allowed value, caused the raise rock discharge.

Figure 6. Structure of the rock body of the right side of R-3/890.

As the rocks of the 890 m level are medium stable and unstable and as the rock body cannot stay solid with the stress exceeding the allowed value, the body is of 'no-risk' class.

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