Assessment of Stress-Strain and Shock Bump Hazard of Rock Mass in the Zones of High-Amplitude Tectonic Dislocations

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Abstract. The paper analyses geodynamic processes in the development of the Talnakh and Oktyabrsk deposits, which have complex geological structure. It demonstrates the results of the forecast estimation of seismic energy released on the contact surface of the fault plane of type I and II tectonic dislocations when stoping approaches. The article discusses the geodynamic processes occurring during the mining of the Talnakh and Oktyabrsky deposits of complex geological structure. The results of predictive assessments of seismic energy released at the contact surface displacement of a tectonic disturbance type I and II at the approach of remediation. For practical use of the obtained graph of the dependence of critical distance from the front of the treatment works to a tectonic disturbance on the magnitude of the angle of internal friction.

Introduction

The Talnakh and Oktyabrsk deposits contain approximately 90% of ore reserves in Norilsk district, (north-east region of Russia), which constitutes about 35% of measured nickel reserves, almost 10% of copper, approximately 15% of cobalt and more than 40% of world platinoid reserves [1-3]. Mining and Metallurgical Complex (MMC) Norilsk Nickel development strategy involves upgrading manufacturing facilities in order to increase copper-nickel ore extraction before 2020. At the same time, intensive mining at MMC Norilsk Nickel deposits requires conducting ore mining at greater depths under dynamic occurrence of rock pressure. As shows, one of the major reasons of shock bump hazard in mining is block structure of rock formations [4]. Therefore, the study of geodynamic processes occurring in rock formations in the zones of tectonic dislocations is quite relevant for MMC Norilsk Nickel.
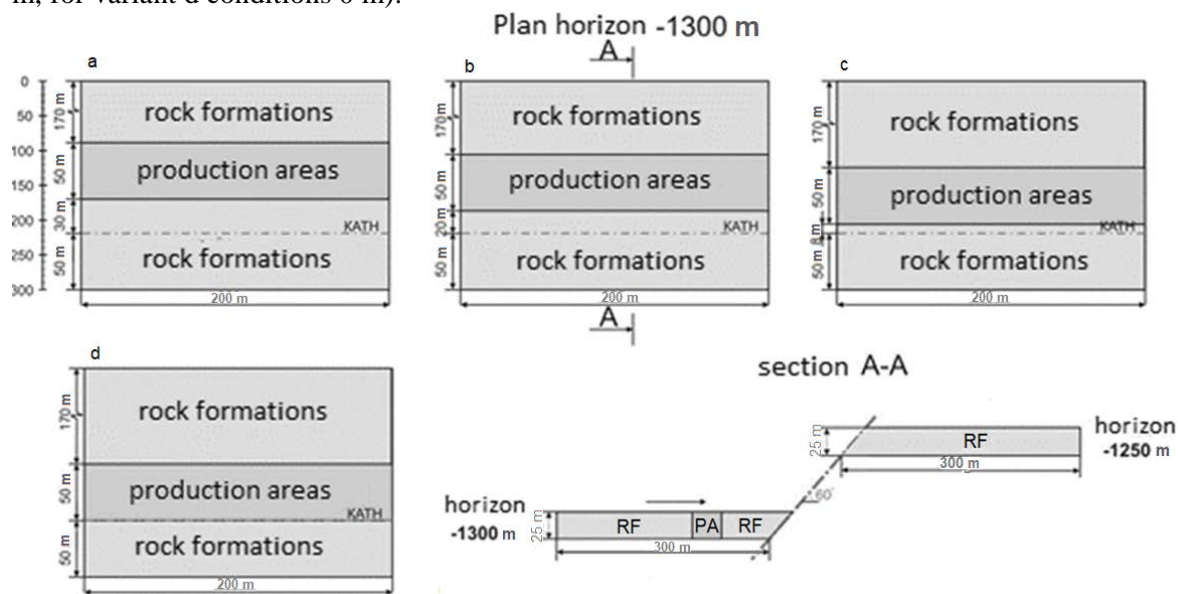
Strong and fragile ores of the Talnakh and Oktyabrsk deposits are prone to shock bumps, which leads to the destruction of mine workings and elements of mine structures when certain mining geological and technical conditions combine. The rock mass is characterized by high-level tectonic fracturing which is involved in the formation of tectonically stressed zones and is the main reason for rock bursts during mining [5-7]. The tectonic structure of the region is represented by large normal and reverse faults: the main line of the Norilsk and Kharaelakh fault, the system of the Zapadny faults, the Gorny fault, the Bolshoy horst, the Central graben, etc. The morphology of the fault line enables to distinguish between four types of dislocations: a smoothed plane, along which the edges of the dislocation are closed; a zone of crush filled with cemented material; a zone of crush filled with friable material; and a range of parallel contiguous planes, each of which is characterized by low amplitude, however, their combined amplitude can reach significant figures. At the same time, according to the research in [6], type I and II tectonic dislocations are most widespread. For type I a zone of maximum tension is formed on the edges of a tectonic fault. This tension is hazardous and is characterized by visible signs of dynamic occurrence of rock pressure, which gradually decrease with distance. Zones of crush are typical for type II tectonic dislocations. There are no visible signs of rock pressure. However, high-level shock bump hazard is possible during mining, when approaching these dislocations [4].

One of the major factors in the formation of shock bump hazard in the zones of tectonic dislocations is the shift amplitude of the edges of a dislocation [8-9]. It is due to the fact that when stoping in a rock mass with high-amplitude tectonic dislocation, in comparison with low-amplitude dislocations, there is a much larger opportunity to implement rock elastic deformation energy through movements along the planes of a block with the release of a significant amount of seismic energy in the form of powerful mining and tectonic shocks [10]. As the assessment of stress condition of a rock mass during mining in the zones of low-amplitude tectonic dislocations was covered in detail [5], the subject of this paper is to study the correlation between the changes of stress-strain state and rock competence near the fault lines of high-amplitude tectonic dislocations.

Estimation

In order to solve the problem we conducted a numerical experiment using automated software system PRESS 3D URAL [10]. The tectonic dislocation was modelled as a normal fault with a fault line strike $AZ_{TD}=90$ and fault line slope angle $\alpha=60°$. The amplitude of the tectonic dislocation was taken to be equal $A_{tn}=50$ m. Internal friction angles were taken in the range of $\rho_{TD} \in[4,0-20,0]$. Ore and rock physical and mechanical properties: oremodulus of elasticity $K_o=5.3\cdot10^4$, adjacent rock modulus of elasticity $K_D=8.2\cdot10^4$, adjacent rock Poisson's ratio $\mu=0.25$. According to the data of geologic cross-sections, the thickness of ore body on the average was taken equal to $m_r=25$ m. The depth of work was 1300 m (from earth surface to ore body surface). The size of the stoping zone was taken to be equal 50 m. Figure 1 shows calculation diagrams for numerical modelling. In order to assess how the approach of a mining face influences changes in stress-strain state of a fault line we gradually decreased the distance between the high-amplitude tectonic dislocation and the stoping zone (for variant a conditions this value was 30 m, for variant b conditions 20 m, for variant c conditions 8 m, for variant d conditions 0 m).

a – the distance of 30 m, *b* – 20 m, *c* – 8 m, *d* – 0 m.

Figure 1. Calculation Diagrams at Different Values of the Distance between a Goafand a Tectonic Dislocation

During the formation of fracture (sliding) zones, elastic strain (seismic) energy is released on the contact surface of the fault line. The value of this energy can be determined according to [11]:

$$\Delta E = \left(\frac{2 \cdot (1 + \mu) \cdot \tau_{max}^2}{K_D} \cdot \Delta_0 \cdot \sum_{i=1}^{N} S_i \right) \cdot 10^6$$

where ΔE – the search value of elastic strain (seismic) energy, J,

μ – Poisson's coefficient of the calculated element (point) in the plane of a tectonic dislocation,

K_D – modulus of elasticity (Young's modulus) of the calculated element (point) in the plane of a tectonic dislocation, MPa,

τ_{max} – maximum pressure tangent lines on the contact strength certificate (along the plane of the fault line), MPa,

Δ_0 – the size of a natural clearance on the contact surface of the fault line which occurs at the sliding along the line, m,

S_i – the area of the calculated element in the plane of the tectonic dislocation where sliding was noted, m^2,

N – the number of calculated elements in the plane of the tectonic dislocation in which sliding was noted.

The values Δ_0 are taken to be equal the following: for type I dislocations – Δ_0 =0.003-0.005 m, for type II dislocations – Δ_0=0.0003-0.0005 m. The values τ_{max} are taken to be equal the following: for type I dislocations – τ_{max}=10-15 MPa, for type II dislocations – τ_{max}=1.5-2.0 MPa.

2.1. A criterion of shock bump hazard

As a criterion of shock bump hazard we chose the way of its assessment based on the permissible value of seismic energy influx. According to paper [12], the recommended critical value of seismic energy is equal to $10^{2,5}$ J (316 J). Table 1 shows the results of the modelling for variants *a–d* conditions.

Table 1 Forecast Seismic Energy Values

Parameters of tectonic disturbances (TD)		Value of the area movements S_{TD} and seismic energy E							
		Option *a* (30 m)		Option *b* (20 m)		Option *c* (8 m)		Option *d* (0 m)	
Type TD TH	ρ_{TD}. degree.	S_{TD}. m^2	E. J	S_{TD}. m^2	E. J	S_{TD}. m^2	E. J	S_{TD}. m^2	E. J
II-type $\tau_{max} =$ 1.5 MPa $\Delta_0 =$ 0.0005 m	4.0	17749.6	608.8	26899.4	922.6	29999.4	1028.9	32249.3	1106.1
	6.0	7999.8	274.4	13549.7	464.7	22649.5	776.9	26599.4	912.3
	8.0	1549.9	53.2	7649.8	262.4	15899.6	545.3	22049.5	756.3
	10.0	-	-	2349.9	80.6	8849.8	303.5	18499.6	634.5
	12.0	-	-	299.9	10.3	5899.9	202.4	15899.7	545.3
	14.0	-	-	-	-	2899.9	99.5	13149.7	451.0
	16.0	-	-	-	-	549.9	18.9	10599.7	363.6
	18.0	-	-	-	-	-	-	6349.9	217.8
I-type $\tau_{max} =$ 15 MPa $\Delta_0 =$ 0.005 m	20.0	-	-	-	-	-	-	2149.9	73738.9
	22.0	-	-	-	-	-	-	-	-
	24.0	-	-	-	-	-	-	-	-
	26.0	-	-	-	-	-	-	-	-

3. Results and Discussion

The analysis of the results presented in Table 1 shows that as the stoping zone approaches a type II tectonic dislocation, there is a possibility of movements in the plane of the fault line and a seismic event with energy equal to 10^3 J. According to the classification in [13-14], such energy values can result in the intensive formation of flaws in the rock, pressure fractures and strain burst. When stoping approaches a type I tectonic dislocation a seismic event with energy equal to $7.3 \cdot 10^4$ J can occur. It can lead to the destruction of the edges of ore body, broken support structures, and open fractures going into the depth of the rock mass. For the practical use we provide a graph which shows correlation between the critical distance from stoping to tectonic dislocations and the internal friction angle which characterizes a type of disturbance (Fig. 2).
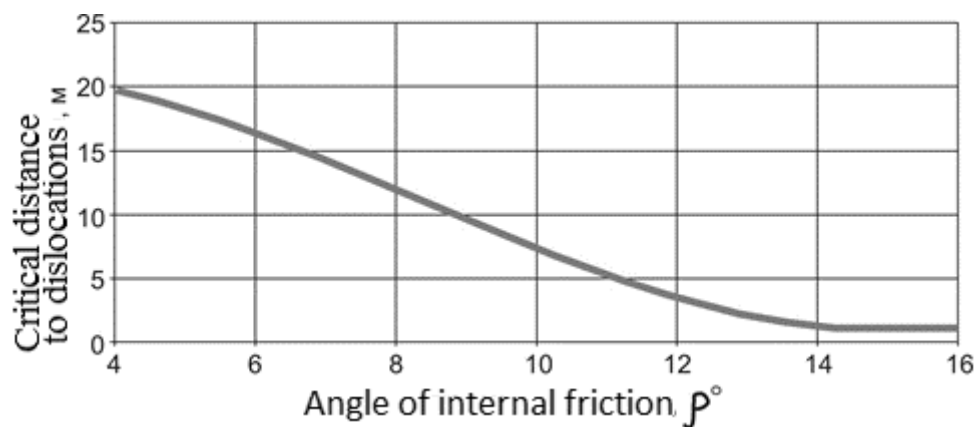

Figure 2 Minimum Permissible Safe Distance between Stoping and Zones of High-amplitude Tectonic Dislocations

4. Conclusion

Thus, the use of this method allows making an early prediction of geodynamic hazard during stoping in ore mass with high-amplitude tectonic dislocations. Further research will focus on geomechanical basis for permissible parameters of prevention activity (well unloading) in order to lower the level of shock bump hazard in an ore mass with tectonic flaws.

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