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MUNDARIJA

STUDY OF STRESS-STRAIN STATE OF ROCKS

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Annotatsiya. *Ushbu maqolada O‘zbekiston rudali konlarida tog‘ jinslarining cho‘zilish-siqlanish (stress-strain) holatini o‘rganish masalasi muhokama qilinadi. Tog‘ jinslarining stress-strain holatini o‘rganishga oid kompleks tadqiqotlar olib borildi. Tadqiqotlarda geodinamik xususiyatlar, tektonika va konlarni o‘zlashtirish sharoitlari hisobga olingan. Bu esa tog‘ urilishlarining kritik chuqurlikda yuzaga kelishini aniqlash va o‘rganilayotgan konlardagi stress-strain holatining to‘liqroq tasvirini olish imkonini berdi. Taklif etilgan konlarning urilish xavfliligini baholash usuli hozirgi davr uchun eng dolzarb hisoblanadi, chunki kon ishlari chuqurlashtirilmoqda va shu chuqurliklarda tog‘ bosimi dinamik shaklda namoyon bo‘lmoqda. Maqolada, shuningdek, Kochbulak va Qizil-Alma konlari sharoitida turli litologik qatlamlar uchun tog‘ urilishlarining kritik chuqurliklari bo‘yicha aniq natijalar keltirilgan.*
Kalit so‘zlar: *tog‘ jinslarining stress-strain holati; tog‘ urilishi xavfi; slitani bo‘shatish usuli; geodinamik va tektonik sharoitlar; Koxbulak va Qizil-Alma konlari.*

Abstract. *The article discusses the issue of studying the stress-strain state of rocks in the ore deposits of Uzbekistan. A complex of studies of the stress-strain state of rocks was carried out. Features of geodynamics, tectonics and field development conditions are taken into account in the work to determine the critical depth of occurrence of rock impacts, as well as to obtain the most complete picture of the stress-strain state of the studied deposits. The proposed method of assessing the impact hazard of deposits is the most relevant for this period, due to the deepening of mining operations to a critical level and the manifestation of rock pressure in a dynamic form at these depths. The article also provides specific results of the critical depths of occurrence of mountain impacts for various lithological strata in relation to the conditions of the Kochbulak and Kyzyl-Alma fields.*
Keywords: *stress-strain state of rocks; rock burst hazard; slot unloading method; geodynamic and tectonic conditions; Kochbulak and Kyzyl-Alma deposits.*

Аннотация. *В статье рассматривается вопрос изучения напряжённо-деформированного состояния горных пород в рудных месторождениях Узбекистана.*

Проведен комплекс исследований напряжённо-деформированного состояния пород. В работе учтены особенности геодинамики, тектоники и условий разработки месторождений для определения критической глубины возникновения горных ударов, а также для получения наиболее полной картины напряжённо-деформированного состояния исследуемых месторождений. Предлагаемый метод оценки удароопасности месторождений является наиболее актуальным на сегодняшний день в связи с углублением горных работ до критического уровня и проявлением горного давления в динамической форме на этих глубинах. В статье также приведены конкретные результаты критических глубин возникновения горных ударов для различных литологических слоёв применительно к условиям месторождений Кочбулак и Кызыл-Алма.

Ключевые слова: *напряжённо-деформированное состояние горных пород; удароопасность месторождений; метод щелевого разгрузки; геодинамические и тектонические условия; месторождения Кочбулак и Кызыл-Алма.*

Introduction

The problem of increasing the safety and efficiency of underground mining of ore deposits occupies an important place in the further development of the mining industry of the republic. During underground mining, rock pressure, especially in conditions of deep horizons with high tectonic stress of the rock mass and the complexity of its geological structure in mines, leads to sudden destruction of sections of the developed massif and rock bursts.

The peculiarity of the geotectonic position of the hazardous deposits of Uzbekistan is their confinement to a tectonically active region of the earth's crust. Such conditions are characterized by the effect of a very uneven stress state of sections of the rock massif, which is under the influence of both man-made and neotectonic processes, which in turn affects the geomechanical state of the rock massif.

For effective management of rock pressure, it is necessary to use methods and means for assessing and monitoring the geomechanical state of the massif, fully taking into account the features of geodynamics, tectonics and conditions of deposit development.

At present, various methods have been developed and applied for in-kind measurements of the stress-strain state (unloading method, slot unloading, borehole strainmeters, photoelastic sensors, etc.)

2 Experimental research

During the research process, we determined the initial stresses of the rock mass using the slot unloading method according to the methodology of the Mining Institute of the Ministry of Ferrous Metallurgy of the former Soviet Union.

The essence of the slit unloading method consists in the formation of a slit (Figure 1, 2) with a radius of 0.3 m and measuring the deformation of its walls on the slit. Such a zone of unloading of the rock

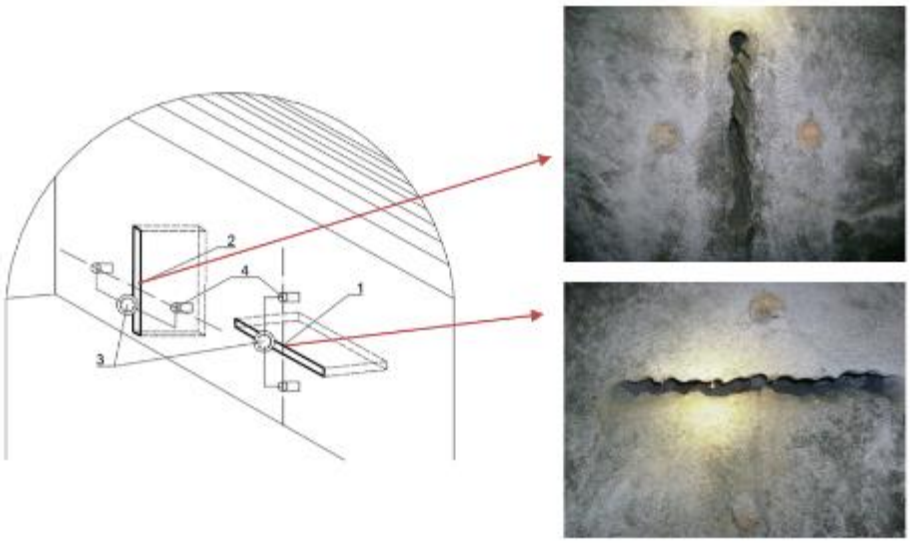
mass in this method reaches three sizes of the slit. In this case, the influence of the different modulus of rocks included in this zone, the interaction of structural blocks and their residual stresses is significantly reduced.

The magnitude of the stress (MPa) acting perpendicular to the plane of the gap is determined by the formula (1).

$$\sigma_{\perp} = U_{AB} E\pi / \left[8R - \pi l\left(1 - K_{II(\perp)} + \mu K_{II(\perp)}\right)\right] \quad (1)$$

where U_{ab} - is the deformation of the massif between points A and B after the formation of the crack, cm; E - is the modulus of elasticity of the rock, MPa; R - is the radius of the crack, cm; *l* - is the distance between points A and B, cm; $K_{II(\perp)}$ - are the stress concentrations $\sigma_{\perp}$ in the directions perpendicular and parallel to the crack, which are taken from the graphs in Figures 1, 2.

In the slot unloading method, special devices are provided for the formation of a slot and the production of measurements. The slot is drilled with a hammer drill by means of adjacent boreholes. To ensure their uniform placement, a template is proposed, thanks to which holes for benchmarks are drilled at a certain distance from the future gap, and then the gap. The removable benchmark is a collet device. Textolite collets are expanded in boreholes thanks to a metal wedge. On the side outer part of the collet there is a polished socket for the indicator rod.



1 – horizontal gap; 2 – vertical gap; 3 - watch micrometer; 4 – rapper.

Figure 1. Determination of stresses using the slot unloading method.

The method consists of selecting a location, drilling the outer boreholes, strengthening the template with wedges in these boreholes, then drilling a hole for benchmarks, strengthening the benchmark, taking the first readings with a clock-type indicator with an accuracy of 0.002 mm. After this, having removed the

template for the benchmarks, a crack with a radius of 0.3 m is drilled according to the main template and a repeat measurement is taken with the indicator. The difference in readings on the indicator determines the deformation of the rocks on the crack. The magnitude of the stresses is determined by the formula (1).

The use of the slit-unloading method allows one to obtain information about the stress in a section of about 1 m. To obtain this information in a large section, especially when the rock mass has a large amount of cracking and heterogeneity, it is necessary to increase the number of slit-unloading measurements.

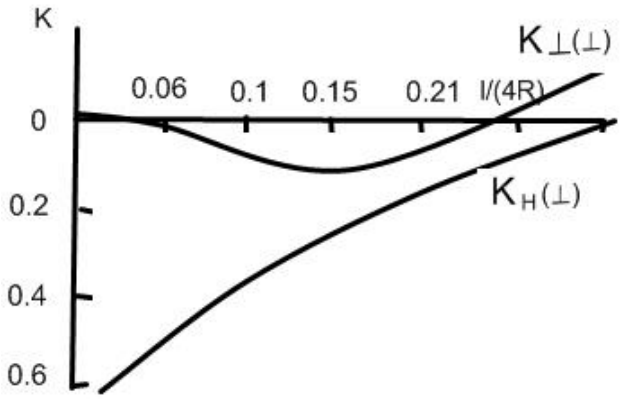


Figure 2. Dependences of the concentration coefficients of the contour part of the unloading gap K on the ratio of the distance between the benchmarks to the gap radius e/(4R) under the action of a load perpendicular to its plane

At the Kochbulak deposit, in-kind measurements were taken on the crosscut and the second northern adit of the 1030 m horizon (14 measurements), on adit 44 and the field adit of the 238 ore body (15 measurements); at the Kyzyl-Alma deposit – in adit No. 15 of the 1165 m horizon, and in the crosscut and adit of the 806 m horizon. The total number of unloading cracks was 29 (table - 1, figures - 3, 4). Based on the results of the measurements, the stresses of the rock mass acting vertically (σ_{ver}), along the strike of ore bodies (longitudinal σ_{lon}), and across the strike of deposits (transverse σ_{tran}) were determined. A total of 267 stress values were determined. Statistical processing of the calculation materials was done using a well-known method.

The confidence interval for determining the average stress values is 12.7 - 40.3% of their absolute values, which corresponds to the accuracy limit of rock stress measurements using modern methods. Therefore, the measured values of initial stresses can be used to assess the rock burst hazard of deposits and determine the parameters of structural elements of underground structures. However, given the complexity of the rock mass structure, in the course of further research, the specified values should be clarified, if possible, by complex in-kind

measurements in various areas of the deposits.

3 Research results

Analysis of the results of determining the initial stresses of the rock massif (Table 1) allows us to note the following. The measurement sections show a scatter of measurement data, and, consequently, of the calculated stresses of the rock massif. The uneven distribution of stresses in the massif is caused by the complex tectonic structure, in particular, the blockiness of the rocks, limited by systems of cracks and faults, as well as the mountainous terrain. The actual vertical stresses of the rock mass are practically equal to the gravitational stresses from the weight of the overlying rocks, equal to γH according to Heim, where γ - is the bulk density of the rocks, MN/m^3, H - is the depth of development. Horizontal stresses directed along the strike of ore deposits are 1.3-1.5 times less than vertical stresses. The stresses acting across the strike of ore deposits have maximum values. They exceed vertical stresses by 1.4 times.

The excess of horizontal stresses σ_{lon} over vertical stresses can be explained by the presence in the massif, along with gravitational stresses, of significant stresses of tectonic origin, supported by modern neotectonic movements of the earth's crust. The presence of the latter was previously established in other ore deposits of Central Asia by I. T. Aitmatov, N. G. Yalymov, V. R. Rakhimov, K. D. Vdovin, G. A. Markovny, and others.

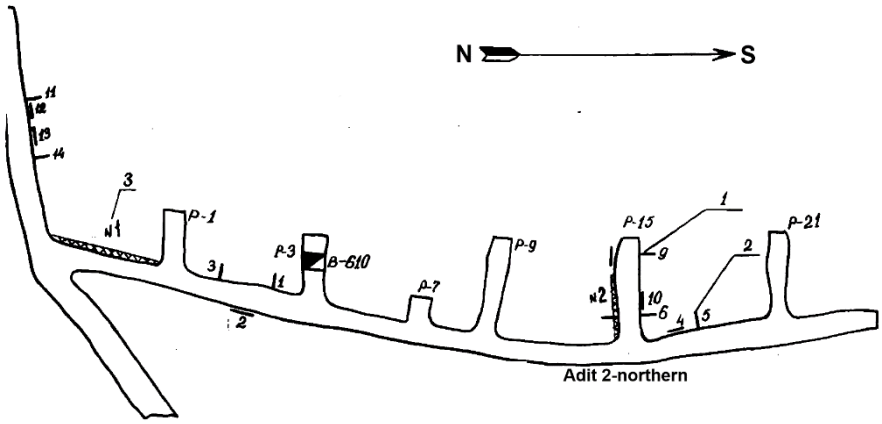


Figure 3. 1,2 – horizontal and vertical unloading cracks and their numbers; 3 – rock fracturing measurements.

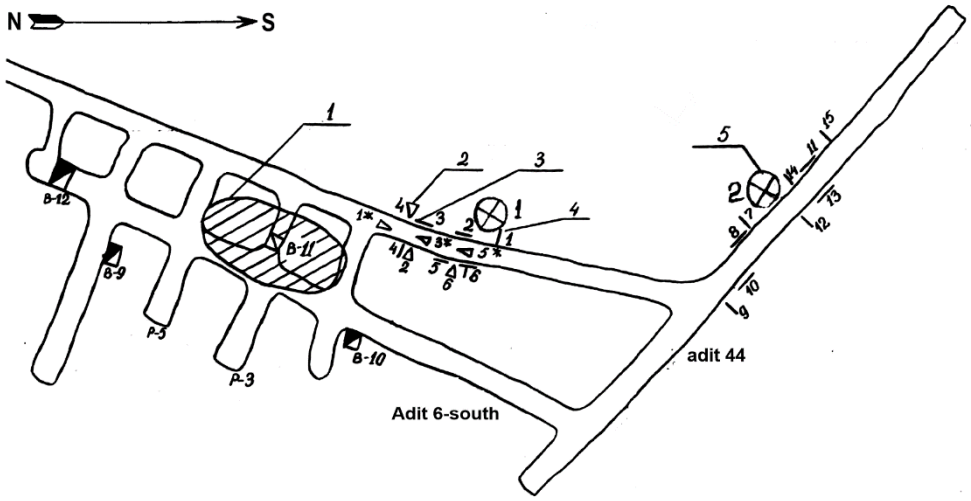


Figure 4.3,4 – horizontal and vertical unloading slots and their numbers.

Table 1.

Characteristics of initial stresses of the rock massif of the Kochbulak and Kyzyl-Almasai deposits

Voltage measurement location	Name voltage	Theoretical Stresses by A.Geim $\sigma_{ver} = \sigma_{lon} = \sigma_{tran} = \gamma H$ MPa	Stresses according to in-kind measurements			$\frac{\sigma_{lon}}{\sigma_{ver}}$	$\frac{\sigma_{tran}}{\sigma_{ver}}$
			Value of stress MPa	Confidence interval			
				in MPa	in %		
Kochbulak deposit							
Crosscut and 2-northern Strike, horizon 1030 m	Vertical	-5,8	-7,1	±2,1	29,6	0,28	1,21
	Longitudinal	-5,8	-2,0	±3,6	180,0		
	Transverse	-5,8	-8,6	±1,6	18,6		
Adit 2-northern mountain 1030 m	Vertical	-7,9	-8,0	±1,1	13,8	0,60	1,05
	Longitudinal	-7,9	-4,8	±1,9	39,6		
	Transverse	-7,9	-8,4	±3,6	42,9		
Adit No. 44 and field adit Ore body 238	Vertical	-6,2	-5,3	±1,0	18,9	1,35	
	Longitudinal	-6,2	-7,2	±1,9	26,4		
	Transverse	-6,2	-7,3	±4,5	60,0		
Average	Vertical	-6,6	-6,8	±1,4	20,8	0,69	1,21

Value	Longitudinal	-6,6	-4,7	±2,5	82,0		
	Transverse	-6,6	-8,2	±3,2	40,5		
Kyzyl-Almasai deposit							
Adit No. 15 Horizon 1165 m	Vertical	-2,6	-2,6	±0,6	23,0	0,77	1,38
	Longitudinal	-2,6	-2,0	±1,2	60,0		
	Transverse	-2,6	-3,6	±0,9	25,0		
Crosscut and adit horizon 806 m	Vertical	-10,7	-14,6	±0,2	1,4	0,71	1,06
	Longitudinal	-10,7	-10,4	±0,4	3,8		
	Transverse	-10,7	-15,5	±0,6	3,9		
Average Value	-	-	-	-	-	0,69	1,21

4 Conclusion

Summarizing the presented data on the geological-tectonic structure and geomechanical state of the rock massifs of the Kochbulak and Kyzyl-Alma deposits, we note the following features.

1. In the deposit massifs, there are unequal-component stress fields in which horizontal compressive stresses predominate, the largest of which are oriented in the sublatitudinal direction. They are 1.1-1.4 times greater than the gravitational component of the weight of the overlying rock mass, thereby indicating the determining influence of tectonic forces in the formation of the natural stress state.

2. The heterogeneity of natural stress fields is replaced by the complexity and peculiarities of the tectonic structure of deposits, which is further enhanced by man-made impacts on the rock mass as a result of mining operations.

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