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V. K. BAGAZEEV[1], *Professor, Doctor of Engineering Sciences*
N. G. VALIEV[1], *Professor, First Pro-Rector*
V. A. STARTSEV[1], *Assistant, Vasiliy.Startsev@m.ursmu.ru*

[1]*Ural State Mining University, Ekaterinburg, Russia*

JUSTIFICATION OF BOREHOLE HYDRAULIC MINING FROM THAWED PLACERS

The article is representing mining method of thawed argillaceous placer mines by hydraulic drilling mining is. Analysis of hydraulic borehole mining shows that in the formation of the wide area, dumps, roof dislocations and dips of overlying rocks occur. The rocks are set in motion because of the disturbance of the equilibrium state. The ability of rocks to maintain balance when creating outcrops determines their stability. The establishment of the parameters of the extraction blocks with saving the dome of natural equilibrium will allow to overcome the deformations described above. A key principle in the justification of the mining method is the stability of rock outcrops.

As a basic mining method of hydraulic drilling mining of thawed placer mines, the single-stall method is considered.

Evaluation of the stability parameters of the roof have been carried out, the value of the dome of natural equilibrium has been determined by the calculation method, experimentally, the size of the limiting span has been established. The limiting span - is a span before the collapse of the roof, the main parameter determining the dimensions of the stall. Measurements and observations were carried out on physical models, in production conditions on the "Uvalnoe" and "Visim" mining districts of the artel "Neiva".

The comparison of theoretical calculations and experimental data is based on the strength characteristics of argillaceous rocks obtained under laboratory conditions using the generally accepted technique of resistance of a weakly cemented rock to shear and a technique for estimating the strength and compressibility of coarse clastic rocks by DalNIIS. Comparing the results of the research, it is established that the method of Borisenko A.A. is the most suitable for determining the dome of natural equilibrium.

The forms and dimensions of the mining stalls are justified, the parameters of which are limited by the dimensions and strength characteristics of the sands and host rocks of placers.

Key words: *mining method, hydraulic borehole mining, stability, roof exposure, strength parameters, argillaceous rocks, placer deposits*
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Introduction

A system of mineral mining is understood as a definite sequence of development and stoping operations coordinated in space and time, with indicated design of production blocks, toward safe and maximized extraction of useful minerals at minimum cost.

Specific features of mineral mining from thawed gold placers include:

— absence of stable roof and clear boundary between gold sand and black dirt;

— presence of rudaceous rocks;

— cavability of roof rocks.

Roof rock caving is possible via boreholes from the surface, which results in sinks, depressions and subsidence, including area around a borehole. In this connection, it is obligatory required to preserve a solid rock block around a borehole or to reinforce the borehole mouth [1–3]. On the other hand, full-thickness mining in a pay bed around a borehole will entail accumulation of coarse material that will prevent stream of gold particles toward the borehole. Based on that, it is required to develop a mining system with preserved stability of a solid block around a borehole and with the small-size extraction zone around the borehole. At the same time, the parameters of the extraction zone (exposed length, width and area) have no long-term stability constraints with the distance from the borehole.

A giant jet washes-out a pocket in the form of a sector (**Fig. 1**) in plan view or, spatially, 1/2 of a sphere sector with the angular point at the jet nozzle. The basic parameters of wash-out in loamy rocks depend on physical properties of rocks, and on pressure head and nozzle diameter of a giant jet [4].

Depending on the size of a mine field, a mining system may be longwall or room-and-pillar. Longwalling is applied to narrow placers (to 10–30 m) when roof support is provided by sidewalls where much quantity of mineral is lost. Room-and-pillar mining involves separate extended panels that may be short or long. Short panels are usually 9×9 or 9×12 m, long panels are 9–4-m wide and 20–60 m long [5]. Rooms are developed by stopes. In room-and-pillar mining, exposures (size of a room) are assumed to be smaller

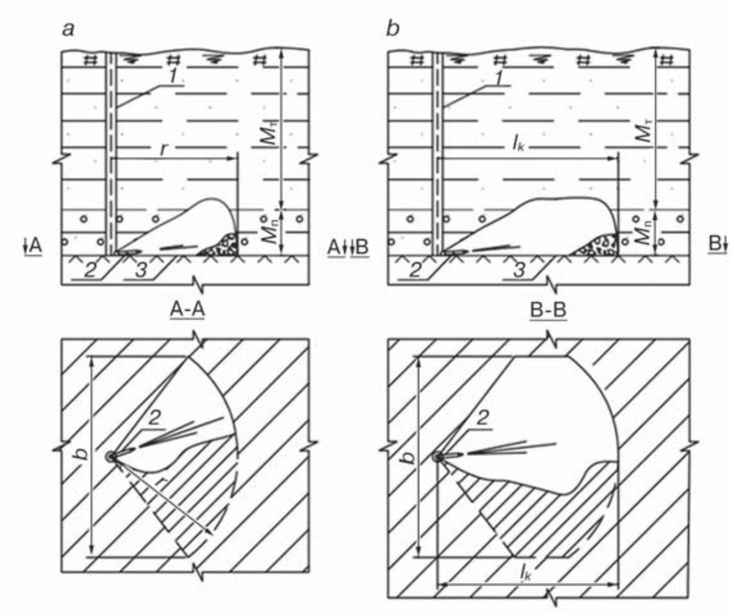


Fig. 1. Sector-like shape of a stope:
a **— short;** ***b*** **— long:**
1 **— borehole;** ***2*** **— borehole tool;** ***3*** **— rock bed;** ***R*** **— wash-out radius;** l_s **— stope length;** ***b*** **— maximum stope width;** M_{PB} **— pay bed thickness;** M_G **— gangue thickness**

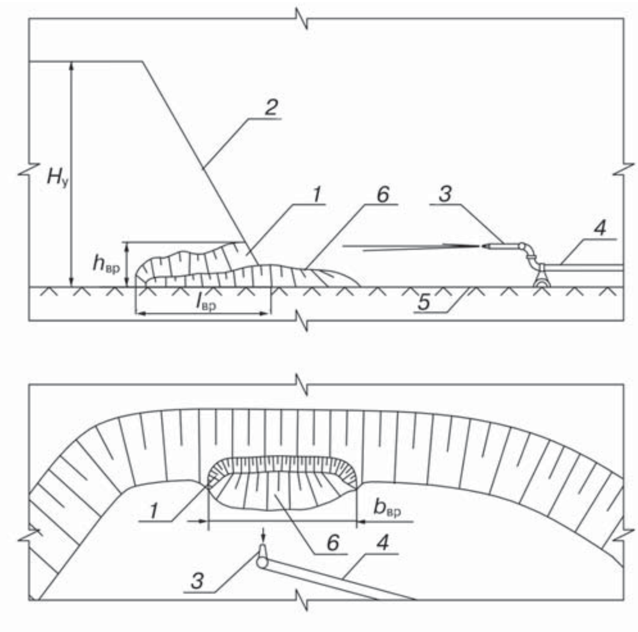


Fig. 2. Jet washing-out schematic:
***1* — cut; *2* — face slope: *3* — jet; *4* — water line; *5* — bed rock; *6* — washed-out rock**

than the ultimate allowable values. Mined-out area in rooms is backfilled or caved [6].

This study assumed the main system of borehole hydraulic mining from thawed placers as the room-and-pillar mining with the controlled caving.

Each room is extracted within a stable span from a separate borehole. Caving is performed when the extraction span reaches the maximum size. In this fashion, the subsequent displacement of rocks takes place after the room is mined-out and the borehole is closed. In this case, parameters of rock mass displacement are not determined [7, 8].

Generally, the exposed span stability, when the stope length l_s (**Fig. 1**) is commensurable with its width b given $\frac{b}{l_s} \geq 2.0-2.5,$ is characterized by the size of the short side of the exposure:

$$L_{span} = b;$$

$$l_s = \frac{L_{span}}{(2.0 \div 2.5)} \tag{1}$$

When $\frac{b}{l_s} < 2-2.5$, and at different load-bearing perimeters of a stope, stability is characterized by the value of an equivalent span L_e [7, 8]. From Slesarev's formula:

$$L_e = 2R_{hr}, \tag{2}$$

where $R_{hr} = \frac{S}{P}$ — hydraulic radius of exposed roof span, m; S — exposure area, m^2; P — exposure perimeter, m.

For a sector-like short stope (Fig. 1):

$$L_e = \frac{\pi \cdot r \cdot \alpha}{(360 + \pi \cdot \alpha)}, \tag{3}$$

for a long stope:

$$L_e = \frac{2\pi \cdot r \cdot \alpha (l_K - \frac{r}{2})}{360 \cdot l_s + \pi \cdot r \cdot \alpha} \tag{4}$$

where r — radius of the sector, m; α — angle of the sector (cutout), deg;

$$\pi = 3.14.$$

The roof span stability condition:

Table 1. Experimental washing-out parameters

Parameter	Notation	Ural placer	
		Visim site	Uvalnoe site
Height of bench, m	H_b	12–13	5
Depth of cut, m	L_{cut}	4.85	1.6
Height of cut, m	H_{cut}	4.38	0.63
Width of cut along the lower edge of bench, m	B_{cut}	11.37	4.3–5.0
Density of rocks, t/m^3	ρ	2.3	2.33
Natural moisture content, %	W	15.0	25.0
Cohesion, MPa	C	0.08	0.035
Natural friction angle, deg	φ	18	8
Natural slope, deg	α		33
Total yield particles of the size — smaller than 2 mm, % — larger than 2 mm, %	 D_2 R_2	 82 18	 90.25 9.75
Tangent of apparent internal friction angle, $\mathrm{tg}\bar{\varphi} = \mathrm{tg}\varphi + \frac{C}{\sigma}$	f	0.59	0.45
Compression resistance of rocks, MPa	σ_{cr}	0.22	0.08
Fracture resistance of rocks, MPa	σ_{fr}	0.07	0.012

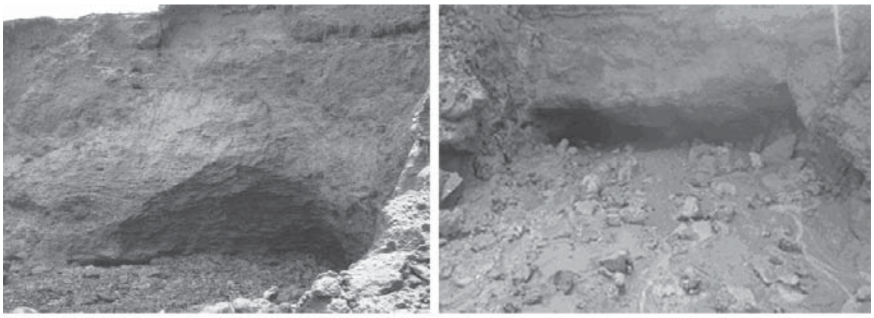
Table 2. Calculation of natural equilibrium arch height h_c, m

Methodology author	Formula	Visim site		Uvalnoe site	
		Calculated	Measured	Calculated	Measured
Protodyakonov M. M.	$f = \text{tg}\varphi$	0.59		0.45	
	$h_C = \frac{L_{us}}{2f}$	9.65	4.38	5.12	0.63
Ritter V.	C, MPa	—	0.08	0.012	0.035
	σ_{fr}, MPa	0.07	—		—
	$h_C = \frac{\gamma \cdot L_{us}^2}{16f \cdot \sigma_{fr}}$	2.73	4.38	2.57	0.63
Borisov A. A.	L_{us}, m		11.37		5.0
	$h_C = (0.21-0.3)L_{us}$	2.4–3.37	4.38	1.05–1.5	0.63
Slesarev V. P., Kuznetsov G. N.	m^*	—	3	—	3
	$h_C = \frac{\gamma \cdot L_{us}^2}{m \cdot R_{hr}}$	14.59	4.38	13.69	0.63

*m — coefficient to account for the hydraulic lock of the roof, e.g. under three-side hydraulic lock: m = 3.

$$L_e \le b_{us} ,$$

where b_{us} — ultimate span (before collapse) of the stope roof, m.



a b

Fig. 3. Experimental erosion:
***a* — cut, Visim site; *b* — cut slot; Uvalnoe site**

Primary section

Placers are composed of loose, low-coherent or weakly cemented clastic sediments. In connection with this, the calculation of an ultimate span assumes that the rock mass is uniform, isotropic and deformable. Under such conditions, the best suitable is the hypothesis on natural equilibrium arch (Ritter V., Protodyakonov M. M., Tsimbarevich P. M., Slesarev V. D.). Such calculations for stopes down to a depth of 200–300 m yield the acceptable results given there are no stresses [9, 10].

With a view to analytical determining of the arch height and the related stope span, the authors measured these parameters during actual hydraulic mining of placers. The studies used guidelines from [11]. The observations and tests were carried out on mining sites at Nevyansk placers (Visim and Uvalnoe sites of Neiva placer mine).

Lab tests allowed physical parameters of loamy rocks extracted from the place of stoping. The main strength characteristics (**Table 1**) were determined using the commonly used method of shear resistance testing of weakly cemented rocks, method of strength and compression tests of coarsely clastic rocks by DalNIIS and, additionally, uniaxial compression resistance was measured on machine VSV-25. The comparison of the obtained results exhibited an insignificant inconsistency.

A cut was washed out directly in bed rocks by a pointed jet. The cut had a shape of a sector in plan view and was an arch in cross section. In this manner, we obtained a physical model of a stope in borehole hydraulic mining [12–17] (**Fig. 2**, **Fig. 3**). The calculation of the wash-out is described in **Table 2.**

Based on the data in Table 2, it can be concluded that:

— the ratio of the calculated and measured arch heights widely ranges: from 0.7 to 14.6;

— the best agreement between the measured and calculated arch heights is achieved with Ritter's V. methodology and Borisov's A. A. generalization — 1.4 times at the average.

Conclusion

In the estimated design of a borehole hydraulic stope, we recommend that the arch height h_C and the span width b_{us} relate as:

$$h_C = 0.25b_{us}, \tag{5}$$

$$b_{us} = 4h_C$$

Based on the stability condition, it is assumed that:

$$L_e = b_{us} .$$

Then, the stope parameters can be calculated from the formulas:

$$_{us} \quad \frac{\pi \cdot \quad \cdot \alpha}{(360 + \pi \cdot \alpha)} , \tag{6}$$

$$b_{us} = \frac{2\pi \cdot r \cdot \alpha (l_s - \frac{r}{2})}{360 \cdot l_s + \pi \cdot r \cdot \alpha} \quad (7)$$

The cross section area of a parabolic arch is given by [13]:

$$F_C = \frac{2}{3} b_{us} \cdot h_C \quad , \quad (8)$$

or $F_C = M_{PB} \cdot b_{us}$,

then:

$$h_C = \frac{3}{2} M_{PB} \ . \quad (9)$$

where M_{PB} is the productive bed thickness, m.

In this manner, using the formulas (5), (7), (8) and considering (9), it is possible to calculate stope designs during borehole hydraulic mining from placers.

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