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Application of hydrohammers of heavy class in the development of marble deposits in mining operations

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Abstract. By development marble deposits in mining operations one of the main technological processes, that ensures minimal losses and dilution with maximum output of commercial products is the process of preparing rocks for excavation. Marble extracted for the production of microcalcite is prepared for excavation by drilling and blasting at most mining enterprises. This inevitably leads to overgrinding in the charging chamber zone and, as a result, to a decreasing in quality indicators (yellowness and whiteness), significant losses of minerals (0–20 mm fraction) up to 30% and a low percentage of high-grade crushed stone in the commodity balance. The paper considers a variant of improving the production technology on the example of the Eleninsky marble Deposit (Chelyabinsk region) by using of heavy-class hydrohammers, which allows to increase the efficiency and completeness of the development of balance reserves by reducing by 5–10% overgrinding and increasing output of a commercial product high grades (40–200 mm).

1. Introduction

Production of mineral fillers from marble on an industrial scale in Russia began relatively recently, at the beginning of the 21st century.

As of 2020, the Russian industry is provided with domestic fillers by only 60%. The deficit is filled with fillers from Turkish, Finnish and European manufacturers.

The main commodity product for the production of marble fillers is crushed stone of the following fractions:

- 1 fraction – 40–200 mm;
- 2 fraction – 20–40 mm;
- 3 fraction – 5–20 mm;
- secondary dropout (0–5 mm) – production of weighting material of drilling fluids.

Currently, marble is prepared for excavation by drilling and blasting, as a result the loss of minerals is increasing significantly and the percentage of output of high-grade crushed stone in the commodity balance is decreasing, which ensures the production of high-quality fillers [1–3].

A similar scheme of work is applied at the Eleninsky marble Deposit. The article presents a variant of changing the process of marble extraction technology, which allows reducing the loss of minerals and increasing the yield of high-grade commercial product at the Deposit under consideration.

Eleninsky marble Deposit is located in Kartalinsky district of the Chelyabinsk region, 3.5 km South-West of village Eleninka. Mineral fillers used in the production of high-quality plastics, rubber and technical products, paint products, modified dry building mixes, office paper, etc. are made from

Eleninsky marble (Figure 1). Eleninsky marble is characterized by high whiteness, low yellowness and very low Fe_2O_3 content.

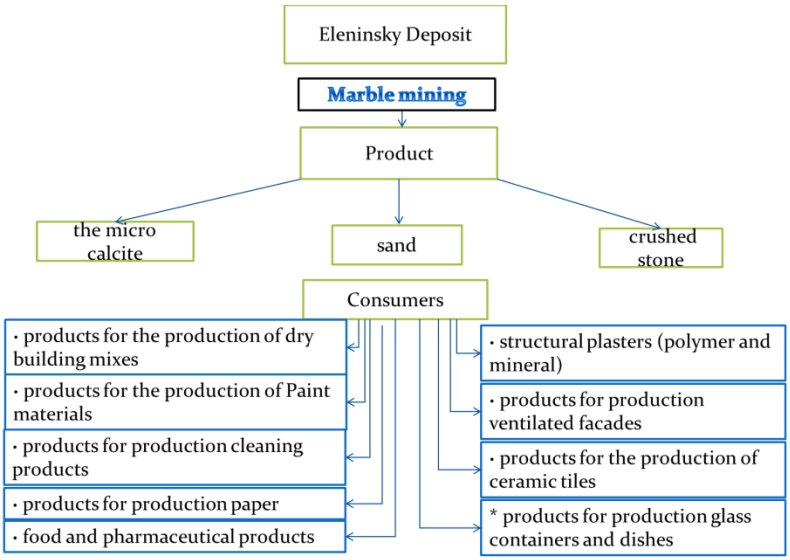

Figure 1. Products and main consumers of the Eleninsky marble Deposit.

2. Research methods

The paper uses a comprehensive research method that includes, along with technological solutions, analysis and generalization of the practice of developing marble deposits, analytical research, methods of technical and economic analysis, as well as economic and mathematical modeling.

3. The main part

As a result of the analysis of the fractional composition of the exploded mineral of the Eleninsky marble Deposit, which is received for further processing, it is established:

- mineral resources, including dilution, received on the DSU:
  - primary dropout (mud fractions), 0–20 mm – 18%
- mineral received for crushing (100%):
  - 40–200 mm – 52%
  - 20–40 mm – 28%
  - 5–20 mm – 6%
  - secondary dropout, 0–5 mm – 14%

It should be noted that in the composition of the mineral received for crushing, 28% is a finished product, 20% is a re-ground product, and only 52% is a raw material suitable for obtaining a liquid commodity product. In the process of crushing and grinding (20–200 mm), the finished product is obtained. The quarry uses drilling and blasting (DBW), which is a traditional method of preparing the rock mass for the extraction of solid minerals.

The assessment of options for preparing marble for excavation was carried out on the basis of economic and mathematical modeling of the use of DBW and mechanical destruction according to the criteria for obtaining the maximum profit P_i of the mining enterprise and achieving the minimum cost C_i of finished products [1, 2, 3, 4]:

$$P_i = Ц_i - \sum_1^n C_{g_i} \rightarrow \max, \quad (1)$$

$$C_i = \frac{\sum C_{g_i}}{V_i} \rightarrow \min \quad (2)$$

Tables 1 and 2 show the annual commodity balance and the cost of work on existing parameters in preparation for the extraction of mineral resources using DBW.

Table 1. Annual commodity balance in preparation for marble excavation with the help of DBW.

Appellation	%	Tons	Sales price (wholesale) RUB/*t* (without VAT)	Profit, RUB. (without VAT)
Annual productivity of the quarry for mineral resources, taking into account dilution	100	750000.00	–	–
Primary dropout (0–20 mm)	18	135000.00	–	–
CSP				
Mineral resources for crushing	100	615000.00	–	–
40–200 mm	52	319800.00	400	127920000.00
20–40 mm	28	172200.00	160	27552000.00
5–20 mm	6	36900.00	160	5904000.00
Secondary dropout (0–5mm)	14	86100.00	100	8610000.00
TOTAL:		615000.00		169986000.00

Table 2. The cost of DBW on existing parameters.

Appellation	%	Tons	Cost of work, RUB/*t* (without VAT)	The cost of DBW per year, RUB (without VAT)
Volume of loosening of DBW	100	750000.00	27.5	20750000,00
Primary dropout(0-20 mm)	18	135000.00	–	–
The oversize (+ 200 mm)	10	75000.00	51	3825000.00
TOTAL:				24575000.00
Output of commercial products		615000.00	–	–
The cost of DBW in terms of one ton of commodity products			39.96	

In order to reduce losses during re-grinding of minerals [1, 2, 7], a variant with modified parameters of drilling and blasting operations (BWR) was considered and several experimental explosions were made. During the experiment, the specific consumption of explosives decreased (up to 10%) and the grid of wells expanded (up to 15%).

As a result, it was possible to reduce the loss of mineral resources by 8%, but at the same time the output of oversized material (+200 mm) was increased almost 5 times. Taking into account the cost of destruction of oversized by hydraulic hammer, the cost of drilling and blasting operations in terms of one ton of commercial products increased by 39.7% (table 3).

Table 3. Cost of drilling and blasting operations during experimental explosions.

Appellation	%	Tons	Cost of work, RUB/*t* (without VAT)	The cost of DBW per year, RUB (without VAT)
Volume of loosening of DBW	100	750000.00	27.5	20625000.00
Primary dropout (0–20 mm)	10	75000.00	–	–
The oversize (+200 mm)	49	367500.00	51	18742500.00
TOTAL:				39367500.00
Output of commercial products		675000.00		
The cost of DBW in terms of one ton of commodity products			58.32	

Thus, the use of this option with the changed parameters of the DBW only partially solves the problem. At the same time, the cost of BWR in terms of one ton of commercial products is increasing significantly.

As an alternative, we consider changing the process of preparing rocks for excavation at the Eleninsky marble Deposit [10–12], in order to reduce the loss of minerals and increase the yield of the commodity product without increasing the cost of finished products.

The annual capacity of the quarry for marble extraction is adopted in accordance with the technical project and is 280 thousand m^3 in a dense body.

The capacity of overburden rocks and useful thickness, the geological structure (Figure 2) and mining conditions of the Deposit determine the conduct of mining operations by the open method.

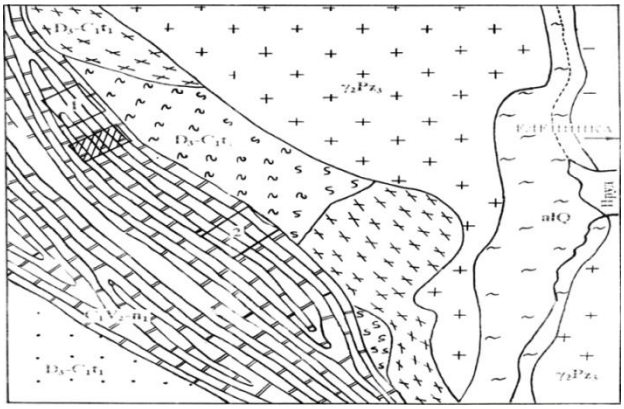

Figure 2. Geological map of the Eleninsky marble Deposit.

The option of non-explosive preparation is considered and the choice of the development system according to N. V. Melnikov is made. The site provides for the use of a transport development system that includes a four-process cyclical technology:

- mechanical loosening of rock mass (heavy hydraulic hammer);
- excavation and loading operations (excavator type mechanical shovel);
- transportation (motor transport);
- dumping and storage (external bulldozer).

On the basis of LLC ‘UK TEK cars’ data management preparation of rocks for excavation heavy hydraulic hammer on the limestone deposits in the quarry LLC ‘Vostochnye Berniki’ and graphite on LLC ‘Taiginsky GOK’ was performed techno-economic modelling (table 4 and 5) [6, 7, 12, 13], the results of which is the decision to carry out pilot testing hydraulic hammer for the preparation of the minerals on Eleninsky field of marbles (Figure 3).

Figure 3. Preparation of marble for excavation with the help of a heavy hydraulic hammer of the company ‘Volvo’ at the Eleninsky marble Deposit.

Table 4. Cost of work by preparing marble for excavation with a hydraulic hammer.

Appellation	%	Tons	Cost of work, RUB/*t* (without VAT)	Costs for hydraulic hammer in year, rbl. (without VAT)
Annual productivity of the quarry for mineral resources, taking into account dilution	100	750000.00	51	38250000.00
Primary dropout (0–20 mm)	5	37500.00		–
Output of commercial products	–	712500.00		–
The cost of mining operations in terms of one ton of commodity products			53.68	

Table 5. Loss of mineral resources and yield of commercial product in preparation for excavation with a hydraulic hammer.

Appellation	%	Tons	Profit, RUB (without VAT)
Annual productivity of the quarry for mineral resources, taking into account dilution	100	750000.00	–
Primary dropout (0–20 mm)	5	37500.00	–
CSP			
Mineral resources for crushing	100	712500.00	
40–200 mm	70	498750.00	199500000.00
20–40 mm	18.5	131813.00	21090080.00
5–20 mm	7.5	53438.00	8550080.00
Secondary dropout (0–5 mm)	4	28500.00	2850000.00
TOTAL:		712500.00	231990160.00

Techno-economic modeling has shown (table 6) that the use of hydraulic hammer heavy class in the mining of marble leads to lower operating costs for the preparation of rocks for excavation by reducing losses, for the conditions on Eleninsky Deposit, at 97500 tons per year and increase the commercial yield of 16 %, including varieties.

Table 6. Technical and economic comparison of options for preparing a mineral for excavation.

Appellation	Hydrohammer		DBW		EFFECT	
	Tons	Sales price RUB/*t* without VAT	Tons	sales price RUB/*t* without VAT	Tons	Ruble per year
Mineral Resources	712500.00	–	615000.00	–	97500.00	–
For crushing						
40–200 mm	498750.00	199500000.00	319800.00	127920000.00	178950.00	71580000.00
20–40 mm	131813.00	21090080.00	172200.00	27552000.00	–40387.00	–6461920.00
5–20 mm	53438.00	8550080.00	36900.00	5904000.00	16538.00	2646080.00
Secondary dropout (0–5mm)	28500.00	2850000.00	86100.00	8610000.00	–57600.00	–5760000.00
TOTAL:	712500.00	231990160.00	615000.00	169986000.00	97500.00	62004160.00

4. Conclusion

The paper describes the solution of an actual scientific and practical problem, which consists in the development and scientific justification of the technology of mechanical preparation of rocks for excavation in the development of marble deposits using a heavy-class hydraulic hammer, which is important for the science and practice of the mining industry.

Main scientific results, practical conclusions and recommendations:

1. It is established, that by using the traditional method of preparing marble for excavation, namely DBW, leads to its over-grinding in the charging chamber zone and as a result to a decrease in quality indicators (yellowness and whiteness), significant losses of minerals (0–20 mm fraction) up to 30 % and a low percentage of high-grade crushed stone in the commodity balance.

2. Change of parameters of drilling and blasting operations by reducing specific consumption of explosives (10%) and expansion of the grid wells (up to 15 %) in terms of Eleninsky Deposit leads to a reduction of losses of minerals 8%, but increases the output of the oversized (+200 mm)in 5 times, and sledsvtie growth in the unit cost of marketable products on 39.7%.

3. Technical and economic modeling has shown that the use of a heavy class hydraulic hammer in the development of marble deposits reduces the operating costs of preparing marbles for excavation by reducing losses at the Eleninsky field by 97.500 tons per year and increasing the yield of commercial products by 16 %, including by grades.

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