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THE NECESSITY OF UTILIZING INTERNAL BLADING AT STEEP-FALLING DEPOSITS

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Abstract: *The article discusses the necessity to form internal blades in deep steep falling deposits. The experience of formation and the scheme of blading of internal blades in open-cast mines with different mining and geological conditions is summarized. The prospective solution of formation of internal blades for deep quarry Muruntau is given and their prerequisites are defined.*

Key words: *quarry, deposit, external blade, waste rock, reexcavation, road transport, spot filling, area, peripheral blade formation, tier, transport distance.*

Introduction.

The distinctive feature of the open method of steep-fall deposits development at the present stage of development is a constant increase in stripping volumes. At the same time, the influence of the environmental factor is increasing, which is associated with the need to alienate land for the placement of external blades, which are a powerful source of dust separation. Under such conditions, one of the fundamentally new technological solutions aimed at improving technical, economic and environmental performance of field development is the development and implementation of technological schemes for the formation of internal blades in the worked-out space of the open pit.

The world experience of open-cast mining shows that the use of mined-out space for internal blades is mainly developed in detail for flat and inclined formations [1,2]. The studies on development of internal blading technology for steep falling deposits of elongated shape have been carried out [3]. Technological schemes of application of internal blades for temporary storage of rock mass, creation of transport communications [4], loading of sides [5], placement of blades on the slope of the side of the pit, which reached the final depth [1], have been developed.

At the same time, the search for technical solutions to reduce stripping costs is conducted mainly in three areas:

- rational combination of different types of vehicles;
- increasing the slope angle of the non-working side of the quarry;
- placement of overburden in the mined-out space of the pit.

Let's consider the third direction, which takes place during the development of Muruntau deposit using the mined-out space of the quarry for placement of rocks and substandard minerals in it. In this case, the mined-out space is considered as a production and environmental resource that allows to significantly reduce the cost of extraction of a mineral and limit the negative impact of mining on the environment. This area of research attracts attention from the standpoint of comprehensive resolution of issues related to the transportation of rock mass, stability of the sides of the quarry and reduction of anthropogenic impact on the environment.

It is known that technological schemes of steep-falling deposits development are determined by geometrical parameters of the deposit, applied development system, type of used transport, etc. At the same time, the volume and distance of rocks movement to blades, as well as the area of alienated land and dust and gas emissions into the environment have the greatest impact on the economic efficiency of field development. It is from the point of view of reducing the impact of these factors on the economics of mining operations that the prospects for using the mined-out space of deep pits in steep falling quarries are considered. As studies have shown, when assessing the technological schemes of internal blading of mined-out space in this case it is necessary to take into account the influence of such factors as geomechanically characteristics of rocks, mining and technical conditions, technology of work in the working space of the quarry, safety requirements and time of existence of internal blades, which determine their main parameters, such as the total height of the blade, the number and height of tiers, place and time of formation, the size of the plan, which should provide the possibility of its use.

In the course of opencast development of deposits there is a great experience in formation of blades in different mining and technical conditions (stable and unstable base; flat, hilly and mountainous relief; single and multilevel construction of blades, etc.) with different location (external and internal) and different methods of safety provision (preservation or refusal to preserve stability of the system "Blade - base" while maintaining stability "Blade - machine"; and controlled movement of rocks in the blade). This experience is systematized taking into account the principles and techniques of using man-made resources [7] and is presented in the form of the developed systematization of blades (Table 1), which is a development of the ideas of Academician N.V. Melnikov.

Methods.

During development of classification of blades, the main as system features are accepted:

1. Space for placement - (natural, artificial).
2. Time of existence of blades - (permanent, temporary).
3. Target function:

- Provision of transport communication between mining sites (bulk transport communications);
- buffer tanks between different types of transport (intermediate warehouses of the CPT complex);
- providing stability of the board (deformation section blade loading, creation of buttresses).

4. Formation method:

- reexcavating to the lower horizons (rockscats);
- using automobile or conveyor transport.

Table 1.

Classification of internal blades

Classification feature	Characteristics of classification feature	Conditions of application
1. By location	1.1. On the final contour of the career. 1.2. On the intermediate contour of the career. 1.3. On a slope of a side of a career.	1.1 Completion of mining operations for part or all of the quarry field. 1.2. Temporary suspension of work on a part of the quarry field. 1.3. The angle of the side slope is less than the angle of repose of the rocks in the blade.
2. According to the conditions of the blade formation	2.1. Does not require additional work 2.2. Requires additional work	2.1 The blade formation may begin at any time. 2.2 The formation of the blade may begin after the holding of congresses, creation of unloading platforms and additional facilities.
3. By number of tiers	3.1. Single tier	3.1. Lack of tier height restrictions.

	3.2. Multilevel	3.2. Presence of Tier Height Limitations
4. How to manage blade stability	1 4.1.1 While maintaining blade stability 4.2. With controlled blade shift	4.1. The height of the blade is limited by the bearing capacity of the rocks of the blade and/or the base. 4.2. The inclination of rocks in the blade and/or base to yield as the load increases with the height of the blade.
5. By method of filling the rocks	5.1. Area 5.2. Peripheral 5.3. Concentrated (dotted)	5.1. The initial stage of blade formation. Weak carrying capacity of rocks in the heap. 5.2. Good load-bearing capacity of rocks in the heap. 5.3. Availability of filled space with steep slopes of natural or man-made origin and the possibility of unloading the rocks into the filled space: • directly from vehicles; • from special structures (overpasses, equipped unloading platforms, etc.).
6. By means of mechanization of blading operations	6.1. With the movement of rocks by bulldozers through the upper edge of the blade. 6.2. With rocks stacking in the blade by the cantilever blade. 6.3. With stacking of rocks in the space to be filled by means of wheeled transport.	6.1. In case of motor transport with unloading to the upper site or slope of the blade. 6.2. The possibility of creating a working site for: • Placement of the conveyor at the peripheral method of blading the rock into the filled space; • Installation of the console spreader at the concentrated method of rock pouring into the space to be filled. 6.3. Creation of conditions for unloading of wheeled transport means directly into the space to be filled without additional movement of rocks by bulldozers.
7. Assignment	7.1. Storage of rocks. 7.2. Ensuring Safety of Mining Works. 7.3. Functioning of structural elements of the quarry.	7.1. The necessity of permanent or temporary storage of rocks. 7.2. Creation of retaining structures to increase stability of rock masses. 7.3. Possibility of forming bulk transport berms and exits. 7.4. Necessity and possibility to create buffer elements in transport systems.

	7.4. Execution of functions of pit technological elements.	
8. By storage time of rocks	8.1. Permanent 8.2. Temporary	8.1 Blade rocks are not potential raw materials. 8.2.a. Blade rocks are potential raw materials. 8.2.b. The blade is located in the area of planned works.
9. Upon preliminary preparation of the foundation	9.1. Does not require 9.2. Requires extensive planning work 9.3.Requires special training	9.1 Dispatching to the existing quarry contour. 9.2 Dispatching to a previously formed blade. 9.3. Creation of overloading, retaining, braking, etc. devices at the base of the blade.
10. Preliminary preparation of the unloading site	10.1. Does not require 10.2. Requires special training	10.1. Square or peripheral placement of rocks in the blade. 10.2. Construction of unloading devices at concentrated (dotted) stacking of rocks in the blade.
11. By method of creating a filled space for the internal blade	11.1. Use of peculiarities of ore bodies placement in a mountain range 11.2 Advance creation of the space to be filled on the part of the career field 11.3. Use of technological features of formation of exhausted space of the quarry	11.1. Advance mining of ore bodies with an exit to the final contour in the part of the quarry field. 11.2. Presence of a quarry field stretched along the stretch of the ore body. 11.3. Presence of areas on the edge of the pit, the angle of slope of which is less than the angle of natural slope of rocks.
12. By the frequency of excavation-loading and bladeing operations	12.1. Not repeated 12.2. Repeat cyclically 12.3. Repeat at transition to the next stage of development with change of	12.1. Possibility of advance development of a part of the elongated pit field with the subsequent one-time filling of the rock for permanent storage. 12.2. Possibility to perform repeated cycle "advance mining - filling - release - advance mining" in adjacent parts of the pit field. 12.3. Consistency of consumer properties of stored rocks and rocks at the base of the blade with their

	conditions to commercial ore	subsequent joint shipment when changing conditions to commercial ore.
13. By the consumer properties of the rocks	13.1. Waste rock-1 13.2. Waste rock-2 13.3. Mineralized rock mass 13.4. Off-balance sheet ore	13.1. No use as a commodity product is envisaged. 13.2. Use as an additional commodity product is envisaged. 13.3. It is considered as a potential source of raw materials for the continuation of the forecast period. 13.4. It is considered as a real source of raw materials for the continuation of the projected period.
14.In relation to the working area of the quarry	14.1 Excavation-loading and blasting operations are separated in the vertical plane and combined in the horizontal plane 14.2 Handling and milling operations are separated in the vertical and horizontal planes	14.1. Work is carried out on adjacent sections of the quarry field. 14.2 The works are carried out on the separated in space areas of the quarry field (on the slope of the side of the quarry, when mining ore bodies with a leading exit to the final contour of the quarry).

Research.

The application of heavy-duty dump trucks in Muruntau quarry as an assembly inner-carrier transport predetermines the bulldozer method of inner stacking, which according to the technology of forming and organization of work is divided into peripheral and square [8].

At the peripheral dump trucks are unloaded on the periphery of the moldboard front in close proximity to the upper edge of the moldboard slope or under the slope. In this case, the rock remaining on the top of the dump site is bulldozed under the slope.

In the case of surface dumping, rock is unloaded from dump trucks over the entire area of the blade or on a large part of it, and then the bulldozer plans a dumped rock layer, and after its compaction cycle repeats.

During implementation of internal dumping in the confined conditions of steep-falling deposits, practically every internal dumping starts with the area dumping along the mined-out space. At the same time, the entire rock is bulldozed into the mined-out space in the direction of the planned development of the blade until a turntable area for dump trucks with a slope angle equal to the angle of natural slope of loose rocks... After formation of the headland with parameters allowing to unload the rock on the top flank or under the slope, the stage of peripheral blade formation in the traditional version begins.

At internal stockpiling it makes sense to single out and separately consider a frequent case of point blade formation at high altitude (Fig.1). This method is characterized by the fact that at high height of rock unloading the time of its accumulation in the stockpile tier before the formation of the unloading pad can be very long.

Fig. 1. Type of the inner blade when it is formed in a precise way at a high-altitude quarry Rochester (USA)

The advantage of this method is the maximum use of the most economical gravitational movement of rock mass and the ability to keep the distance of transporting the rock to the blade constant. The disadvantage is the need for additional measures to ensure the safety of work. They can be both technological methods, such as unloading of dump trucks at some distance from the top flank of the blade and moving the rock into the blade by a bulldozer, and technical measures, such as the organization of trestle dumps (which are widely described and used for dumping on slopes). In the latter case, a barrier is erected at the top edge of the blade, which provides safe unloading of dump trucks under the slope. In spite of the necessity of additional construction works, this method allows to exclude bulldozing works at the dump.

In making a decision on the use of internal dumps and the choice of their structural parameters in the quarries at steep falling deposits the determining factor is the availability of space for their placement. When analyzing the options for placement of such dumps in the Muruntau quarry, the final depth of which is determined in ~1000 m, and the depleted space of the quarry is actively developing in its lower half, it was concluded that it is necessary to study the possibility of placing internal dumps on the slopes of the side of the pit. Implementation of the proposed technological solution assumes the presence in the quarry sections of the side, put in a limiting position, with a slope angle less than the angle of natural slope of rocks. Such area is located on the Western board, the instrument array of which has a block structure with indefinite boundaries, which increases the risk of its deformation when loading the dump. At the same time, mining operations here are brought up to the design depth, which simplifies the solution to the location and parameters of such "overhanging" blade. Nevertheless, such decision to locate the "overhanging" blade requires substantiation of the following definition:

- parameters of potential deformations of the instrument array;
- stress state of the instrument array at loading of the pit slope dumps.

One of the main reasons for deformation of the instrument array in quarries is the occurrence of natural vibrations of the rock block. Such vibrations at the blocks potentially representing a future landslide body, sharply differ from the natural vibrations of adjacent blocks. Seismic waves of natural and anthropogenic (explosive) earthquakes in this block cause increased resonance loads, which, as a result, form a landslide body [31].

Comparison of deformations of sides and dumps of Muruntau quarry with the time of mass explosions showed that ~80 % of them take place within 2 days (on the average, after 38÷40 hours).

During the research the spectral level of horizontal vibrations of rock blocks at the main tone frequency of natural vibrations of the sides of the quarry at the earthquakes with intensity of 7 and 8 MSK, most unfavorable for deep quarry, was accepted as criterion of seismic influence on elements of Muruntau quarry [31 Bykovtsev].

The results of investigations of spectral level of oscillations, actual parameters of deformations and seismograms from mass explosions (see table) for Muruntau quarry have been obtained relations of height H of deformed section of board with resonant frequency f, spectral density of oscillations S from resonant frequency f_{co} and volume of deformation V_{grnd} from spectral density of oscillations S [9,10]:

$$H = 57{,}5\, f^{\,0{,}72}; \qquad S = 3{,}93 f_{co}^{\,0{,}52}; \qquad V_{grnd} = 13{,}0 e^{2{,}3S}.$$

Table 2

Forecasting estimations of deformation volumes of sides of Muruntau opencast mine from seismic impact of mass explosions

Parameters	Significance					
Height of side, ledge, blade or warehouse in the quarry Hc, m	20	30	40	60	80	100
Layer resonance frequency f_{res}, Hz	6,8	4,8	3,9	3,0	2,4	2,1
Frequency range of emission of maximum oscillation energy, f Hz	5.8-7.8	3.8-5.8	2.9-4.9	2,0-4,0	1.4-3.4	1.1-3.1
Average spectral shift density of the system in the resonant frequency range of S_w^{res}, mm.s	0,52	0,47	1,0	1,7	2,6	3,2
Volumes of possible landslides V, thousand.m^3	10-50	7,5-45	70-400	300-1200	800-1600	1300-2500

Analysis of the obtained data allowed to make a forecast of influence of seismic vibrations on stability of sides of Muruntau opencast mine, which showed that in case of unfavorable development the volume of deformations will make up to 200-250 thousand m^3 with the height of deformed layer 100 m. From this it was concluded that the size of single blade on the slope of side should be not less than this value, which allowed to make decision about development of variant with placement of internal 4-level blade from the height of tier up to 120 m on the western side of quarry.

The investigation of the stress state of the instrument array when the slope is loaded with a blade was carried out in a wide range of changes in the object characteristics (height, slope angles, rock properties), as the task was solved under conditions of uncertainty. The influence of additional load (slope) in the upper, middle, lower part and along the whole length of the slope (Fig.2) on the slope stability coefficient was determined under the following parameters: slope height H=500 m; slope angle $\alpha = 30^0$, rock internal friction angle $\varphi = 34^0$, rock clutch with c=55,5 t/m^2, rock density ρ = 2,7 t/m^3 with additional loading density $\rho_0 = 1.8$ t/m.

а) б)

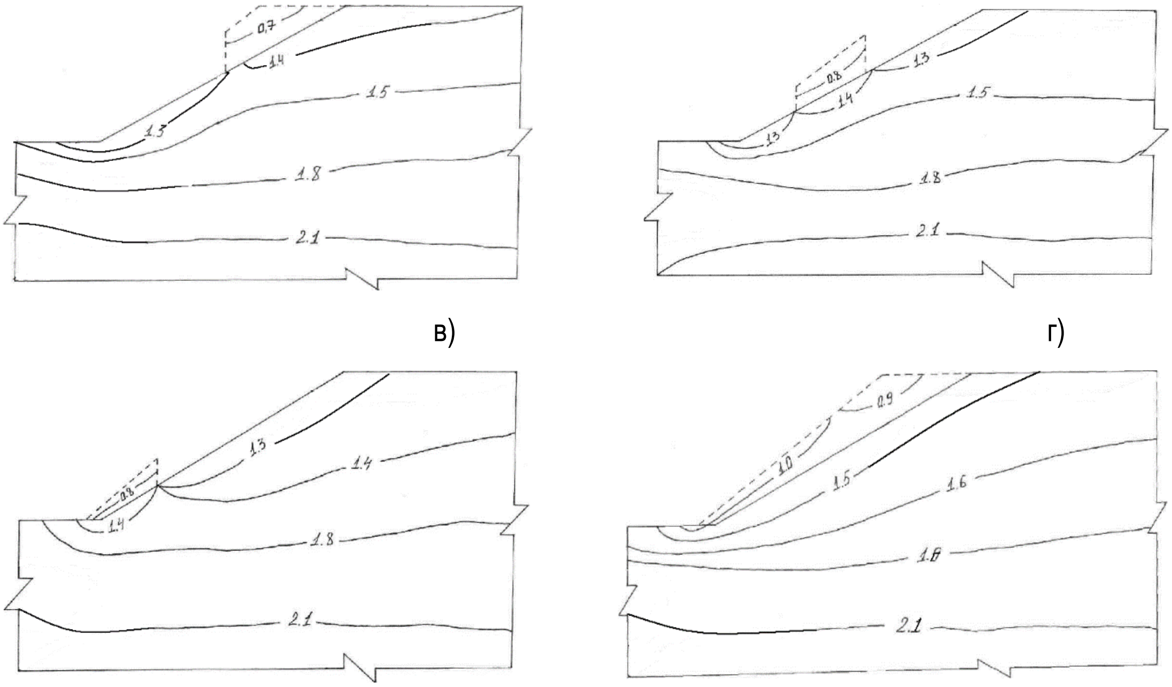


Fig. 2. Distribution of stability coefficient in the instrument array with a blade in the upper (a), middle (b), lower (c) parts and along the whole length of the slope (d).

The analysis of the obtained data shows that in the first three variants the stability of the instrument array in the place of loading the slope by the blade increases by ~ 10%, and in the variant of placement along the whole length of the slope - in the blade array of the instability zone. Such stress distribution can be explained by the increase of the retaining component of gravity.

The influence of the internal friction angle of the rocks in the massif and the "hanging" dump on the stress distribution in the instrument array has been considered by the example of placing two dumps simultaneously in the upper and lower parts of the slope (Fig. 3, 4).

a) б)

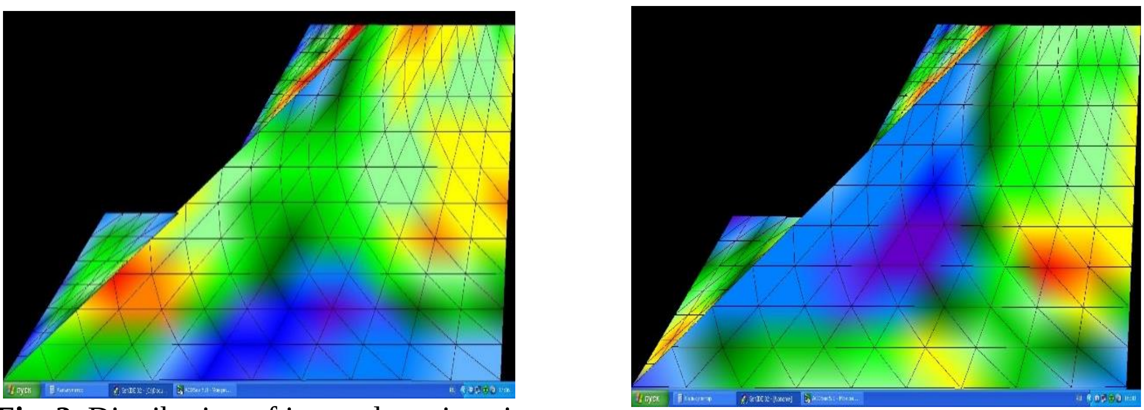


Fig. 3. Distribution of internal tensions in an instrument array at internal friction angle 300 in rocks of a file and 100 (a) and 300 (b) in rocks of a blade:

- compressive stresses; -strengthening tensions

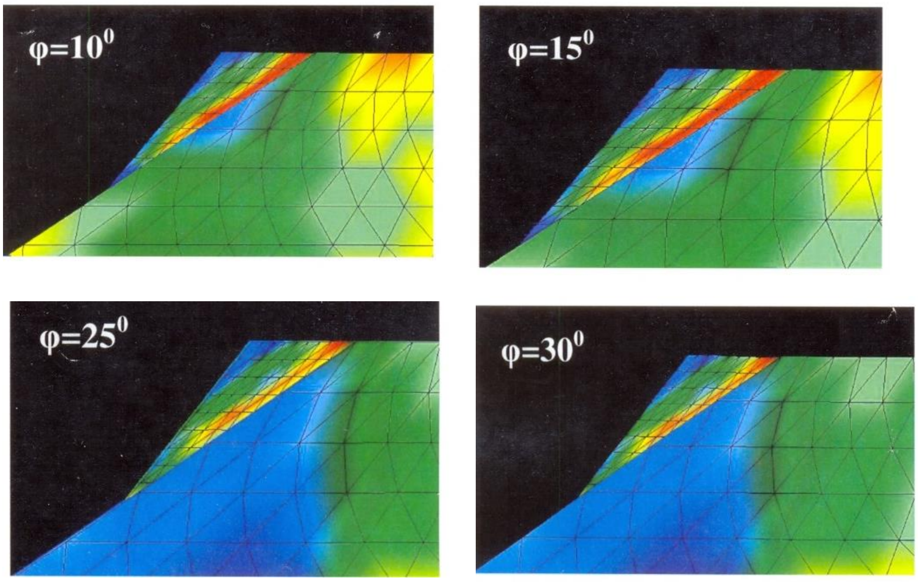
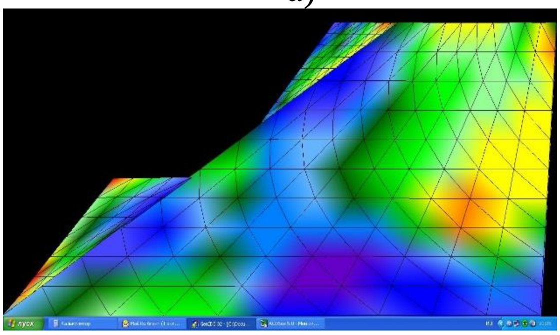


Fig.4. Distribution of internal tensions in an instrument array at constant internal friction angle in its rocks and different angles ϕ in rocks of a blade (symbols on fig.4).

The analysis of the obtained data allowed to establish that the maximum tangential stresses occur in the area of contact of the blade with the instrument array. It follows from the logical conclusion that the most probable development of disturbances will take place in the boundary layer of the blade, not in the instrument array (Fig.3, 4). In this case, the maximum impact of the blade on the instrument array occurs when the internal friction angles in the rocks of the blade and the array coincide.

Fig.5 shows the influence of plastic properties of the rocks of the instrument array on the character and distribution of stresses when it is loaded by the blade.

а)



б)

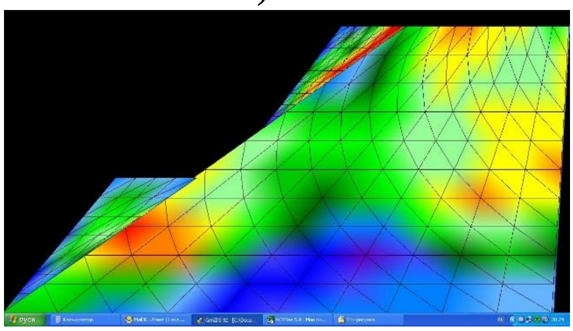


Fig.5. Stress distribution in the loaded instrument array of plastic (a) and rock (b) rocks (symbols in Fig. 4).

The analysis of the obtained images shows that:

- in plastic arrays, the main stresses are of tensile nature and are related to the center of mass of the blade, which significantly affects the instrument array (pushes);

- in rocky ranges, the greatest stresses arise on the boundary layer of the blade, and the influence of the overlying blade is manifested in the zone of the underlying blade, where significant compression stresses are formed.

Mathematical modeling of the influence of the height of the " dangling" blade on the stress distribution in the instrument array (rocks of the array with an internal friction angle of 34^0 and a coefficient of adhesion of 3 MPa, rocks with a coefficient of adhesion of 0.02 MPa) showed that:

- the depth of distribution of tangential stresses in the instrument array is in direct nonlinear dependence on the height of the blade, with increasing height of which its squeezing effect decreases, which is probably due to an increase in its area and entropic redistribution of stresses;

- for an instrument array with a "hanging" blade on the slope, the zone of influence of the blade, the zone of stress relaxation and the zone of pressure of the instrument array are clearly distinguished in the distribution of tangential stresses, while the blade is characterized by uniform stress growth as the distance from its surface increases.

Conclusion.

Therefore, the conducted researches have shown the possibility to place internal dumps on the slope of the western side of Muruntau opencast mine, and when it is extended to the eastern direction to refine deep deposits - technological schemes based on point methods of dumping.

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