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Assessment of the stability of the underworked sides and ledges of the quarry to determine the area of possible location of the shaft

[1*]**Zeitinova Sh.B.**, [1]**Imashev A.Zh.**, [1]**Suimbayaeva A.M.**, [1]**Alzhanov R.H.**, [2]**Makhmudov D.R.**

[1] Abylkas Saginov Karaganda Technical University, Karaganda, Kazakhstan
[2]Tashkent state technical university named Islam Karimov, Tashkent, Uzbekistan

** Corresponding authors email: zeitinova_rmpi@mail.ru*

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ABSTRACT
As known, the main methods of developing solid minerals are open and underground methods. However, an analysis of the world's practice of developing deposits of solid minerals also indicates the widespread use of the combined method of development in the last 50-60 years. Combined development of deposits at domestic and foreign mining enterprises is used due to the variable depth of deposits, which is typical mainly for deposits of steep and inclined fall. The essence of the combined development is that the upper horizons are developed in an open way, and the lower ones are developed underground. In such deposits, the following scheme has become widespread: the initial development of the upper section of the deposit by a shallow quarry (up to a depth of 80-100 m, sometimes more), then the construction of an underground mine, carried out in parallel with the completion of the quarry reserves. When opening sub-quarry reserves subject to underground mining, the resulting quarry space can be used. The penetration of vertical and inclined opening workings, tunnels, and exits from the berm sides or directly from the bottom of the quarry has become widespread. In parallel mining of reserves by open and underground methods, the joint use of transport workings is widely used for the delivery of ore mass from the quarry and underground mine, the placement of an underground crushing complex, auxiliary, and repair facilities in the quarry itself. In addition, the method of refining sub-quarry reserves with the opening of the underground part outside the quarry space has been widely used. After the end of open-pit mining, underground horizons are opened by capital mining workings (vertical, inclined shafts, tunnels).

Keywords: combined development, vertical mine roadways, shafts, underground reserves, open pit, side, slope.

	Information about authors:
Zeitinova Sholpan Bekzhigitovna	*Ph.D., senior lecturer, Abylkas Saginov Karaganda Technical University, Ave. Nursultan Nazarbayev, 56/2, 100027, Karaganda, Kazakhstan. Email: zeitinova_rmpi@mail.ru*
Imashev Askar Zhanbolatovich	*Ph.D., associate professor, Abylkas Saginov Karaganda Technical University, Ave. Nursultan Nazarbayev, 56/2, 100027, Karaganda, Kazakhstan. Email: a.imashev@kstu.kz*
Suimbayaeva Aigerim Maratovna	*Ph.D., senior lecturer, Abylkas Saginov Karaganda Technical University, Ave. Nursultan Nazarbayev, 56/2, 100027, Karaganda, Kazakhstan. Email: aygerim_86@mail.ru*
Alzhanov Rustem Hairullaevich	*Doctoral student, Abylkas Saginov Karaganda Technical University, Ave. Nursultan Nazarbayev, 56/2, 100027, Karaganda, Kazakhstan. Email: alrus1983@mail.ru*
Makhmudov Dilmurod Raxmatjonovich	*Ph.D., Tashkent state technical university named Islam Karimov, University street, 2, Tashkent, Uzbekistan. Email: dmahmudov@yandex.ru*

Introduction

Depending on the depth of the deposit, reserves lying below the quarry are most often opened by Vertical and inclined barrels that pass outside the quarry and are used for mining, unloading and lifting people, and ventilation. The advantage of these opening schemes is to significantly reduce the construction time of the underground mine and reduce capital costs by reducing the length of the main and auxiliary underground workings.

A fairly large practical experience of mining enterprises in Kazakhstan, Russia, and far abroad shows the widespread use of a combined method of mining solid mineral deposits using vertical mine trunks to open the underground part of the field [[1], [2]].

In addition, M. Khudey, M. Radosavlevich, and S. Vuynich studied the selection of the location of the vertical trunk using multimodel analysis in the Velenye region of Slovenia [[3], [4]].

Attention was paid to the work of researchers Qing Yu, Jinrong Ma, Hideki Shimada, and Takashi Sasaki, which provides a quantitative analysis of the model of the impact of mining operations on the stability of the mine shaft [[3], [5]].

Experimental part

There are many specific engineering and geomechanical tasks that affect the efficiency of using combined excavation. Let's try to highlight the tasks that interest us, which are directly related to the choice of location and location of the main opening workings – in our case, vertical trunks.

The tasks that form the scientific and methodological basis for solving the scientific and technical problem of choosing a safe place for laying vertical trunks during combined digging include [6]:

1. *Selection of the method of field discovery, taking into account the specifics of mixed development*. In contrast to the traditional underground method of development of deposits, the peculiarity of choosing a safe scheme of opening during mixed development is the presence of open pit space and a displacement zone of rocks in contact with the quarry, that is, the fact of the emergence of a new factor of Man-Made influence. It is known that zones of sliding and falling rocks are formed around the quarry space, within which it is not allowed to place the main opening workings and carry out other works without applying the measures provided for in the safety rules.

2. *Determination of the size of the rock displacement zone around the contour of the quarry, extending from the surface of the earth to the final depth of the quarry*. This is one of the most important tasks, the solution of which directly depends on the choice of the location of vertical trunks.

3. *Determination of the maximum depth of the quarry*, where the contour coefficient of the trench is equal to the boundary coefficient of the trench. This parameter, first of all, serves to assess the possibility of an underground transition from an open method of development and determines the boundaries of this transition. On the other hand, this task is directly related to the discovery of the field, the order of depth and location of vertical trunks, as well as the process of formation, the geomechanical state and the dimensions of the area adjacent to the contour of the quarry, within which the construction of trunks is not allowed [7].

4. *Assessment of the stability of the slope of the quarry side, study of the features of the development of deformations on the slope and slope of the quarry, the influence of the slope on the distribution and value of stresses along the contour of the quarry in the conditions of transition to underground mining*. In the context of the transition to underground development, this process becomes more complex and develops according to an unknown pattern, depending on the conditions of rock formation and the technology of underground development. Any changes in the stress-deformable state of rocks lead to a change in the geomechanical state of the zone of the quarry near the contour, which depends on the choice of the location of vertical trunks. The Basic Laws of these deformations can be predicted with sufficient accuracy on the basis of well-known methods and recommendations before choosing the location of the trunk.

5. *A complex of engineering and geological surveys on the basis of Visual Studies and instrumental measurements on the study of the terrain, the structure of the Earth's surface, the presence of methods of transport routes (railways, highways), geological irregularities, reservoirs, and aquifers, etc. in order to assess and establish the possibility of constructing the mouth of vertical trunks*. It is possible to determine possible areas of surface deformation by means of movement zones. This makes it possible to make a decision on the placement of surface and underground hydraulic structures. The actual angles of movement may be smaller than those designed, so for safety reasons, ground structures are located at a certain distance from the traffic zone. This distance is called a security berm, which is regulated by safety regulations.

Taking into account the displacement of rocks, it is important to establish the boundaries of rock sliding along the entire depth of the quarry in order to determine the area of possible location of pits on the surface. To do this, it is important to know the mechanisms and patterns of its formation, methods for calculating and evaluating the stability of slopes and slopes, and its impact on the process of falling (sliding) rocks along the contour of the quarry, etc. [8].

To determine the location of vertical trunks on the surface of the Earth, it is important to establish the boundaries of rock slides along the contour of the quarry in the combined method. Knowledge of the mechanisms and patterns of their formation, methods of determining and evaluating the stability of slopes, bevels, their influence on the process of falling (sliding) rocks along the contour of the quarry, etc. is of great importance [9].

In connection with the need to switch to mixed geotechnologies in the conditions of one of the fields in the Republic of Kazakhstan "Ushkatyn-3", researchers of Karaganda State Technical University (KarSTU) conducted scientific and experimental studies to justify the size of the trunk (vertical position of the trunk during the transition to underground development). The purpose of this study was to identify a safe zone. For this purpose, in the southern and northern parts of the Ushkatyn-3 quarry, work was carried out to calculate the stability of the slopes and sides of the quarry, the result of which was to determine the value of the location of the vertical mine shaft at the edge of the quarry [10].

Discussion of results

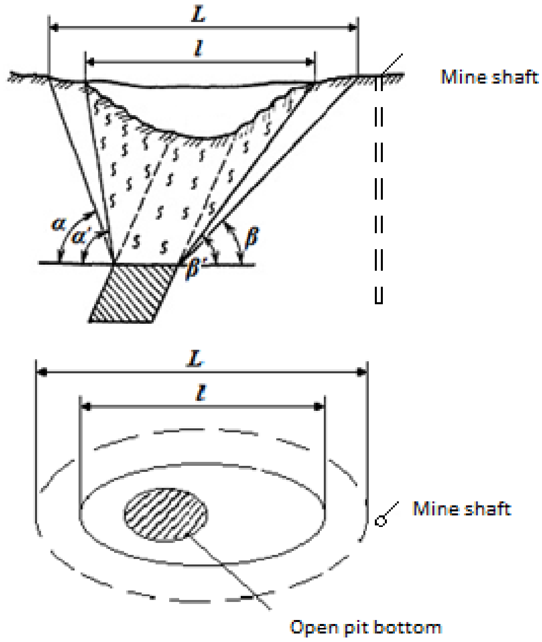
Scientific works of many outstanding scientists such as V.V. Rzhevsky, N.V. Melnikov, K.N. Trubetsky, G.L. Fisenko, E. . Shemyakin, S.G. Avershin, S.I. Popov, M.N. Mashanov, I.I. Popov, R.P. Okatov, P.S. Shpakov, F.K. Nizametdinova, G.G. Poklada, V.N. Dolgonosova, and others are devoted to the study of the stability of the sides of quarries and slopes.

In the course of this work, P.S. Shpakov's calculation classification of the geomechanical line model was used to determine the position of the vertical trunk during the transition to the quarry. It allows us to assess the stability of the quarry side when using the quantitative and analytical methods [[11], [12], [13]].

Figure 1 shows the scheme of displacement and collapse of rocks along the contour of the quarry after open-pit processing.

The essence of the research on the stability of slopes and slopes in the quarry to justify mixed development is that the designation of the sliding surface and boundaries of rocks along slopes and bevels opens up opportunities for determining the safe location of vertical trunks, taking into account the sliding factor of rocks. The figure shows the location of the mine shaft outside the rock displacement zone.

An approach based on the assumption that a collapse prism or sliding prism is formed in the massifs of beeches and beeches is widely used to assess the stability of the sides of quarries and beeches. As an example, we will consider the essence of a number of methods presented in the works [[14], [15]].



L – rock displacement zone; *l* – rock fall zone; *α, β* – rock displacement angle; *α΄, β΄* - the angle of fall

Figure 1 – Mountain range movement scheme

So, in the work [[15], [16]], the conditions for the stability of slopes with this approach are presented as follows:

$$\Sigma Si > \Sigma Ti \quad (1)$$

where ΣSi is the sum of the holding forces on the weakest surface of the prism;

ΣTi is the sum of the shear forces on the same surface.

The slope stability fund coefficient is as follows:

$$n = \Sigma Si / \Sigma Ti \quad (2)$$

n = 1 the surface is called the threshold or sliding surface. Rock shear resistance is determined as follows:

$$\tau = \tau_0\ \sigma n\ tg\varphi \quad (3)$$

where τ_0 is the adhesion of rocks;

σn-normal voltage to the shear site;

τ is the tangential voltage acting in the shear zone;

ϕ is the internal friction angle.

In the case of a flat task, taking into account the dependence (1) is obtained:

$$\Sigma Ti = fcp\ \Sigma Ni\ L\ \tau cp \quad (4)$$

where ΣNi is the sum of normal (retaining) forces on the sliding surface;

τsr-the average value of the coefficient of friction and adhesion on the entire sliding surface;

L-the length of the sliding Surface (line in a flat task).

$$fcp = tg\varphi cp \quad (5)$$

To calculate the stability of the slope, use the calculation scheme shown in Figure 2, which shows the slope scheme with a round cylindrical sliding surface. An array of rocks bounded by the surface of the ABC and the circular cylindrical sliding surface of the AS1 and the constant vertical bare height of the rocks of the SS1 is divided into vertical strips A of the same width. As points of application of the mass of Qi strips, their average height is conditionally selected. By decomposing the mass of the Qi bands into tangents and normal components on the sliding surfaces, you get Ti and Ni.

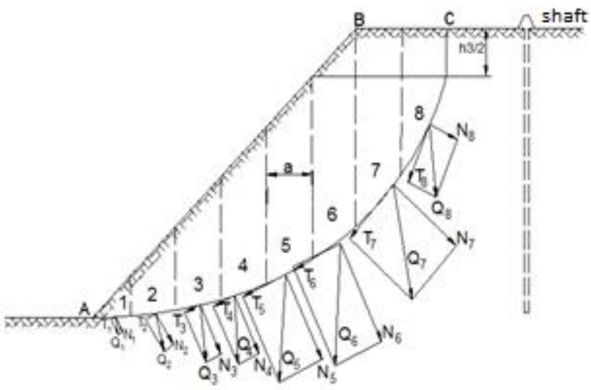


Figure 2 - Calculation of stability slope schemes using a circular cylindrical sliding surface

After the transformations, the slope stability fund formula (6) is obtained:

$$n = \frac{f_{cp} \Sigma N_i L \tau_{cp}}{\Sigma T_i} \quad (6)$$

In the upper part of the slope, there is a vertical segment of the slide line SS 1. This surface (tear line) is formed under the influence of tensile stresses hπ/2. It is recommended to determine this value by the dependence proposed by G.L. Fisenko [16]:

$$h_{\pi/2} = \frac{2\tau_0}{\gamma} ctg\left(\pi/4 - \frac{\varphi}{2}\right) \quad (7)$$

In the conditions of the ushkatyn-3 field, scientific and experimental work was carried out to determine the rational location of vertical mine shafts using these methods. For this field, the weighted average value of the rock strength coefficient on the M.M. Protodiakonov scale was 10. Taking into account the strata of rocks, the following angles of Motion are assumed: δ = 65; β = 50; β1 = 50. For the southern and northern parts of this quarry, stability calculations were performed for the geomechanical model of the uneven slope of the quarry side, as a result of which the location of the barrel was determined [[17], [18]].

Calculations were made for 5 sections that characterize the southern and northern parts of the ushkatyn-III quarry. The calculation of the stability of rocks in the quarry was made according to known methods. All methods take into account the physical and mechanical properties of rocks and the depth of development. Studies were conducted to determine the location of the vertical trunk under the condition of sliding of the Rock line. Below are the sliding zones laid out on the cross-section 1-1 of one of the five slices [19] (Figure 3).

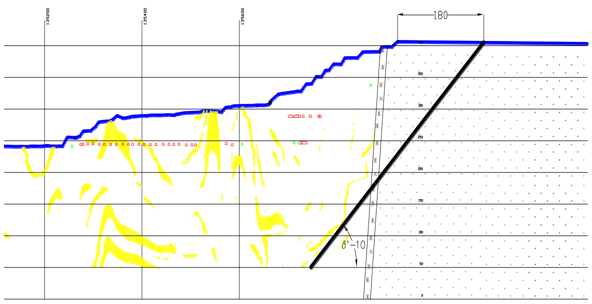


Figure 3 - 1-1 sliding zone by cross-section

5 lines of rock displacement zones were obtained by conducting profile lines in sections.

The following safe distances were determined by the calculations: 180 m; 165 m; 115 m; 0 m; -100 m.

By connecting the points of origin of the lines from movement to the surface of the Earth [20], a zone was finally obtained, within which it was not recommended to place a vertical trunk (Figure 4). The entire area located outside this zone is characterized by the integrity of an array of rocks that have not been affected by mining operations in the quarry. Inside this zone, located outside the contact zone of the quarry, the array is unstable, and the location of the trunk in it can lead to severe deformation and destruction of the trunk.

The mine shaft must be located outside the area shown in the figure. This method allows us to determine the safest place for the construction of

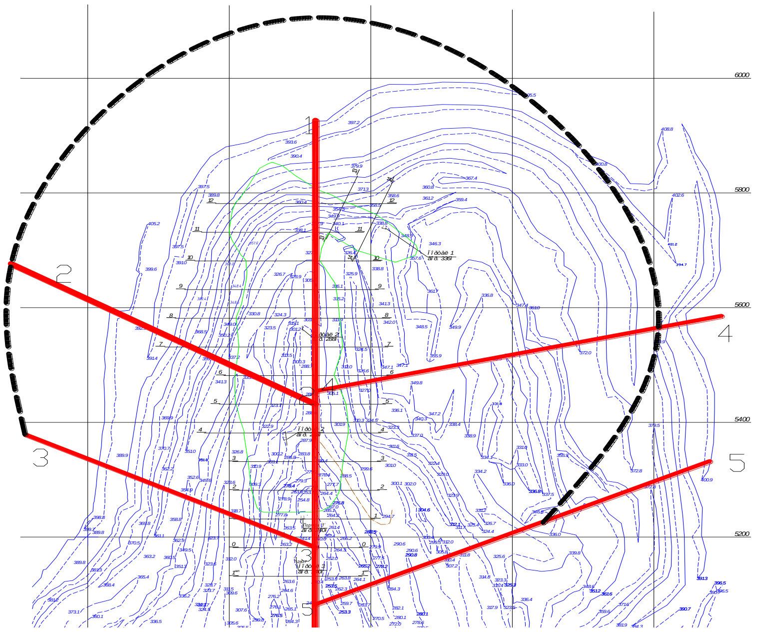


Figure 4 – Rock displacement zone in the northern part of the ushkatyn-3 quarry

vertical trunks in the combined technology of mineral deposit development under the conditions of displacement of massif rocks in the contact zone of the quarry.

Conclusions

When choosing the place of placement of trunks, it is necessary to provide for the possibility of surface treatment during underground work. Leaving protective centers near the trunk, if such a decision is made, will allow maintaining the stability and integrity of the array directly near the trunk, but no more. But the condition of the slopes and pits of the quarry may change. Carrying out underground mining operations in the impact zone of the quarry causes a redistribution of stresses in the treated massif and significantly changes the stability of the slopes and the surrounding area of rock displacement.

Conflict of interest

On behalf of all authors, the corresponding author declares that there is no conflict of interest.

Gratitude

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Оқпандардың ықтимал орналасу орнын анықтау үшін карьердің өңделген ернеулері мен кемерлерінің тұрақтылығын бағалау

[1]Зейтинова Ш.Б., [1]Имашев А.Ж., [1]Суймбаева А.М., [1]Альжанов Р., [2]Махмудов Д.Р.

[1]Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Қарағанды, Қазақстан
[2]Ислам Каримов атындағы Ташкент мемлекеттік техникалық университеті, Ташкент, Өзбекістан

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ТҮЙІНДЕМЕ
Белгілі болғандай, қатты пайдалы қазбаларды игерудің негізгі тәсілдері ашық және жер асты тәсілдері болып табылады. Алайда, қатты пайдалы қазбалар кен орындарын игерудің әлемдік тәжірибесін талдау соңғы 50-60 жылда аралас игеру әдісінің кеңінен қолданылуын көрсетеді. Отандық және шетелдік тау-кен кәсіпорындарында кен орындарын аралас игеру кен орындарының өзгермелі тереңдігіне байланысты қолданылады, бұл негізінен тік және көлбеу құлау кен орындарына тән. Аралас қазудың мәні-жоғарғы деңгейжиектер ашық түрде, ал төменгі деңгейжиектер жер астында қазып алынады. Мұндай кен орындарында негізінен келесі схема таралды: кен орнының жоғарғы бөлігін терең емес карьермен бастапқы игеру (кейде 80-100 м тереңдікке дейін), содан кейін карьердің қорларын өндірумен қатар жер асты кенішінің құрылысы. Жер асты игеруге жататын карьер астындағы қорларды ашу кезінде пайда болған карьерлік кеңістік пайдаланылуы мүмкін. Берм борттарынан немесе тікелей карьердің түбінен тік және көлбеу ашылатын қазбалардан, штольнялардан, құламалардан үңгілеу кең таралған. Қорларды ашық және жер асты тәсілдерімен қатар өңдеу кезінде карьерден және жер асты кенішінен кен массасын шығару, жер асты ұсақтау кешенін, карьердің өзінде қосалқы және жөндеу шаруашылықтарын орналастыру үшін көлік қазбаларын бірлесіп пайдалану кеңінен қолданылады. Сонымен қатар, карьер астындағы қорларды карьерлік кеңістіктің шегінен тыс жер асты бөлігін ашумен аяқтау әдісі кеңінен қолданылды. Ашық тау-кен жұмыстары аяқталғаннан кейін жерасты горизонттары күрделі тау-кен қазбаларымен (тік, көлбеу оқпандармен, штольнялармен, гезенкалармен) ашылады.
Түйін сөздер: аралас игеру, тік қазбалар, оқпан, карьер астындағы қорлар, карьер, ернеу, қиябет.

Авторлар туралы ақпарат:

Зейтинова Шолпан Бекжигитовна	*PhD докторы, аға оқытушы, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Н.Назарбаев даңғылы, 56/2, 100027, Қарағанды, Қазақстан. Email: zeitinova_rmpi@mail.ru*
Имашев Аскар Жанболатович	*PhD докторы, қоғамдастырылған профессор, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Н.Назарбаев даңғылы, 56/2, 100027, Қарағанды, Қазақстан. Email: a.imashev@kstu.kz*
Суимбаева Айгерим Маратовна	*PhD докторы, аға оқытушы, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Н.Назарбаев даңғылы, 56/2, 100027, Қарағанды, Қазақстан. Email: aygerim_86@mail.ru*
Альжанов Рустем Хайруллаевич	*Докторант, Әбілқас Сағынов атындағы Қарағанды техникалық университеті, Н.Назарбаев даңғылы, 56/2, 100027, Қарағанды, Қазақстан. Email: alrus1983@mail.ru*
Махмудов Дилмурод Рахматжонович	*PhD докторы, Ислам Каримов атындағы Ташкент мемлекеттік техникалық университеті, Университетская көшесі, 2, Ташкент, Өзбекістан. Email: dmahmudov@yandex.ru*

Оценка устойчивости подработанных бортов и уступов карьера для определения области возможного расположения стволов

[1]Зейтинова Ш.Б., [1]Имашев А.Ж., [1]Суймбаева А.М., [1]Альжанов Р.Х., [2]Махмудов Д.Р.

[1] Карагандинский технический университет имени Абылкаса Сагинова, Караганда, Казахстан
[2]Ташкентский государственный технический университет имени Ислама Каримова, Ташкент, Узбекистан

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АННОТАЦИЯ
Как известно основными способами разработки твердых полезных ископаемых являются открытый и подземный способы. Однако, анализ мировой практики разработки месторождений твердых полезных ископаемых указывает также на широкое применение в последние 50-60 лет комбинированного способа разработки. Комбинированная разработка месторождений на отечественных и зарубежных горнодобывающих предприятиях применяется в связи с переменчивой глубиной залегания месторождений, что характерно в основном для залежей крутого и наклонного падения. Сущность комбинированной разработки заключается в том, что верхние горизонты разрабатываются открытым способом, а нижние подземным. На таких месторождениях распространение получило в основном следующая схема: первоначальная отработка верхнего участка залежи неглубоким карьером (до глубины 80-100 м иногда более), затем строительство подземного рудника, осуществляемое параллельно с доработкой запасов карьера. При вскрытии подкарьерных запасов, подлежащих подземной разработке, может использоваться образовавшееся карьерное пространство. Большое распространение получила проходка с берм бортов или непосредственно со дна карьера вертикальных и наклонных вскрывающих выработок, штолен, съездов. При параллельной отработке запасов открытым и подземным способами широко применяется совместное использование транспортных выработок для выдачи рудной массы из карьера и подземного рудника, размещения подземного дробильного комплекса, вспомогательного и ремонтного хозяйств в самом карьере. Кроме того, широкое применение получил способ доработки подкарьерных запасов со вскрытием

	подземной части вне пределов карьерного пространства. После окончания открытых горных работ подземные горизонты вскрываются капитальными горными выработками (вертикальными, наклонными стволами, штольнями, гезенками).
	Ключевые слова: комбинированная разработка, вертикальные выработки, ствол, подкарьерные запасы, карьер, борт, откос.

	Информация об авторах:
Зейтинова Шолпан Бекжигитовна	*Доктор PhD, ст.преподаватель, Карагандинский технический университет имени Абылкаса Сагинова, пр.Н.Назарбаева, 56/2, 100027, Караганда, Казахстан. Email: zeitinova_rmpi@mail.ru*
Имашев Аскар Жанболатович	*Доктор PhD, ассоциированный профессор, Карагандинский технический университет имени Абылкаса Сагинова, пр.Н.Назарбаева, 56/2, 100027, Караганда, Казахстан. Email: a.imashev@kstu.kz*
Суимбаева Айгерим Маратовна	*Доктор PhD, ст.преподаватель, Карагандинский технический университет имени Абылкаса Сагинова, пр.Н.Назарбаева, 56/2, 100027, Караганда, Казахстан. Email: aygerim_86@mail.ru*
Альжанов Рустем Хайруллаевич	*Докторант, Карагандинский технический университет имени Абылкаса Сагинова, пр.Н.Назарбаева, 56/2, 100027, Караганда, Казахстан. Email: alrus1983@mail.ru*
Махмудов Дилмурод Рахматжонович	*доктор PhD, Ташкентский государственный технический университет имени Ислама Каримова, улица Университетская, 2, Ташкент, Узбекистан. Email: dmahmudov@yandex.ru*

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