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# STUDY OF RE-EXTRACTION OF ORES FROM MCC WITH FIELD PREPARATION IN CONDITIONS OF THE COLLAPSE AREA

# ИССЛЕДОВАНИЕ ПОВТОРНОЙ ВЫЕМКИ РУД ИЗ МКЦ С ПОЛЕВОЙ ПОДГОТОВКОЙ В УСЛОВИЯХ ОБРУШЕННОЙ ЗОНЫ

# ДАЛАЛЫҚ ДАЙЫНДЫҚПЕН КАМЕРА АРАЛЫҚ ТІРЕКТЕН КЕНДЕРДІ ҚАЙТА АЛУ МҮМКІНДІГІ ШӨГІНДІЛЕРДІҢ ЖЫЛЖУ АЙМАҒЫН ЗЕРТЕУ

***Abstract.*** *Justification of the technology for repeated ore extraction from deposits with preparation in complex mining and geological conditions of collapsed zones and subsidence troughs based on a rating indicator. To address the set tasks, theoretical and experimental studies were conducted to analyze the stages and sequence of developing remaining reserves, as well as methods for substantiating geomechanical parameters and assessing the value of mineral resources. Based on these studies, technological schemes were proposed to enable efficient repeated extraction of ore reserves from pillars with preliminary field preparation and determination of the order of development for specific sections. The first to be developed is block 54, followed by blocks 22-23-24, blocks 15 and 15-15 south in areas with overlapping deposits, and finally block 7bis of the "Annenskaya" mine (VGR). Technical and economic calculations confirmed the feasibility of extracting ore reserves from these blocks, despite the challenging conditions of collapsed zones and subsidence troughs.*

***Keywords****: Field development, underground technology, technological blocks, mining horizon, delivery drift, geomechanical state of the massif, mining horizon, Annenskaya mine.*

***Аңдатпа.*** *Зерттеліп орынған аймақтарының күрделі тау-кен техникалық жағдайларында далалық дайындықпен КАТ (камера аралық кен-тіректі)-ден кенді қайта алу технологиясының негіздемесі. Камера аралық кен-тіректің геомеханикалық параметрлерді негіздеу және пайдалы қазбалардың құндылығын анықтау әдістерін қолдана отырып, қалған қорларды тұтастардан қайта өңдеу үшін орындай отырып, қорларды өңдеудің кезеңділігі мен тәртібін теориялық, эксперименттік зерттеу жүргізу арқылы жүзеге асырылды. Зерттеулердің негізінде далалық дайындықпен және нақты қаралған блоктарда тарту реттілігінің тәртібін айқындай отырып, КАТ-дан қалған кен қорларын қайта өңдеу мүмкіндігінің технологиялық схемалары негізделді, кезектілікпен-бірінші кезекте пысықтауға 54-блок, бұдан әрі 22-23-24-блок, Оңтүстік 15 және 15-15-блоктар тартылады. қабаттасқан кен орындары, содан кейін «Анненская» шахтасының 7бис блогы жылжымалы мульдасы бар құлаған аймақтардың күрделі тау-кен жағдайларында, сондай-ақ орындалған техникалық-экономикалық есептеулер негізінде осы блоктардағы кен қорларын кен орындарынан қазу тиімді болып табылады.*

***Түйін сөздер:*** *Кен орындарын игеру, жерасты технологиясы, Технологиялық блоктар, өңдеу көкжиегі, жеткізу штрегі, массивтің геомеханикалық жағдайы, өңдеу көкжиегі, «Анненская» шахтасы.*

***Аннотация.*** *Обоснование технологии повторной добычи руды из месторождений с подготовкой в сложных горно-геологических условиях обрушенных зон и мульд сдвижения на основе рейтингового показателя. Для решения поставленных задач были проведены теоретические и экспериментальные исследования, направленные на анализ стадийности и порядка разработки оставшихся запасов, а также методы обоснования геомеханических параметров и оценки ценности полезных ископаемых. На основе этих исследований предложены технологические схемы, которые позволяют эффективно осуществлять повторную добычу рудных запасов из целиков с предварительной полевой подготовкой и установлением последовательности разработки на конкретных участках. В первую очередь в работу вовлекается блок 54, затем блоки 22-23-24, блоки 15 и 15-15 юг в местах пересекающихся залежей, и в завершение блок 7бис шахты «Анненская» ВЖР. Проведенные технико-экономические расчеты подтвердили целесообразность разработки рудных запасов в этих блоках, несмотря на сложные условия зон обрушения и мульд сдвижения.*

***Ключевые слова:*** *Разработка месторождений, подземная технология, технологические блоки, горизонт отработки, доставочный штрек, геомеханическое состояние массива, горизонт отработки, шахта «Анненская».*

*Introduction.* The prospective priority of sustainable development of underground ore mining in difficult mining conditions with depletion of mineral resources is the obvious use of geotechnology with repeated extraction from abandoned ore reserves concentrated in inter-chamber (ICC), belt (LC), barrier (BC) and panel pillars (PC), which are structural elements of the room and pillar development system. This problem of ore extraction from abandoned pillars has been considered by many authors in ore and coal deposits (Lushnikov et al, 2013, Neverov et al, 2003). However, it is necessary to consider more widely the possibility of using the technology of this system, taking into account world experience and modern achievements of science and technology, in order to optimize extraction and ensure safe development of mineral deposits. Based on the mining and geological, mining and technical conditions, different versions of the room and pillar mining technology are used in the development of horizontal and very flat deposits (0-120) with an ore body thickness of 3-8 m of average and below average ore value.

Analysis of the application of this technology in world practice shows that in addition to the classic version, there is a room and pillar system with mechanized extraction of angular pillars, which are widely used in the development of ore deposits in the Carlsbad Basin in the USA, as well as in the Saskatchewan Basin (Eremenko at al, 2016, Eremenko at al, 2015, Analysis of the possibility No. 04-3.1.4-9-52 2019). In this case, the dimensions of the mining panels vary from 500 to 900 m. The variety of this system using different pillar shapes (rectangular, square, diamond-shaped) depends on the sequence of technological operations and the ore delivery means used.

Room and pillar systems are used in the development of potash ores at the Starobin deposit (Eremenko at al, 2016, Tishkov, 2018, Couto, Green, 2018). There is experience of pillar systems in the Navarre basin (Spain) and the Mulhouse basin (France), however, the deposits are currently not operating. The room and pillar system of development according to the "chevron" or "Christmas tree" pattern is carried out during extraction at the North Yorkshire deposit in England. There are various types of this system, in foreign literature it is sometimes also called "time control" technology, since they are used in weak rocks with a rapid advance of the cleaning front (FOR) and the maximum possible extraction (Bekbergenov, 2017; Imansakipova at al, 2020). The length of such panels reaches from 1000 to 1400 m with a width of 80 to 150 m. For the development of seams with a thickness of 1.2 to 5 m, a room and pillar system with an angular shape of pillars is used. In this case, the development of reserves, depending on the mining and geological conditions, can be carried out in three ways: direct reverse order of development and direct order with subsequent reverse extraction of reserves from the pillars. The size of the working passages and pillars is determined based on technological calculations, in conjunction with the technical characteristics of the mining equipment. The coefficient of extraction of minerals varies from 30 to 90%.

World experience in using this type of technological scheme indicates the possibility of achieving an annual productivity of one face within 0.6 -1.5 million tons per year. However, the modern development of underground mining of natural and man-made ore reserves from the subsoil worked out by the room and pillar system is characterized by unfavorable mining and geological conditions of development, namely a decrease in the content of useful components in the ore, an increase in the share of refractory ores along with insufficient mining and geological information and high volatility of metal prices, which together leads to a violation of the stability of the functioning of the mining and engineering system, the safety of operational work and the integrated development of natural and man-made reserves from the subsoil, in collapsed conditions of ore deposits.

Therefore, the justification of technological schemes and parameters of the mining and engineering system, ensuring its stable functioning in underground mining of copper deposits in unstable market conditions, as well as in complex mining and geological and geomechanical conditions of development, is an important scientific problem. Currently, during underground development of underground mines of the Zhezkazgan deposit, a number of problems are encountered, among which it is necessary to highlight the increase in rock pressure, low quality of ores, aggravated by the presence of small and large rock inclusions in the structure of ore bodies.

The conducted analysis of the world experience of underground development of natural and man-made ore reserves from the depths worked out by the room and pillar system indicates that in domestic and world practice there are numerous examples and results of the application of this system with regular and irregular arrangement of the MCC (Xu C at al, 2023; Zhou J at al, 2022; Tishkov, 2018, Couto, Green, 2018)

The same problem exists in the extraction of ore at the Zhezkazgan deposit, where the share of repeated extraction from the abandoned ore reserves is about 85% at the Zhezkazgan deposit.

The rock massif of the Annensky district is represented by alternating layers of sandstones, siltstones and mudstones with a predominance of red-colored rocks in the total mass. Industrial concentration of copper is found exclusively in gray fine- and medium-grained sandstones. Layers of red sandstones and siltstones do not have mineralization. About 80% of the district's reserves are concentrated in deposits with dip angles of 15-35°, over 350 - 8%. A characteristic feature of the Annensky field is the multi-tiered mineralization. The deposits are located on 9 ore-bearing horizons, including 23 overlapping ore packs (Bekbergenov, 2017, Analysis of the possibility No. 04-3.1.4-9-52 date 2019, No. 03-23-21-747 date 2019). The ore horizons and the ore bodies included in them are separated from each other by interlayers of waste rock with a thickness of 4 to 40 m. The ore bodies have the form of sheet-like deposits, the sizes of which by area vary widely from 0.1 - 0.5 to 1.0 -2.0 km2 and more. In addition to sheet-like deposits, there are ore bodies of ribbon and lens-shaped form with a length of 800 - 2500 m and a width of 100 - 400 m. The nature of the wedging out of ore bodies is rarely distinct; most often the transitions from rich to poor ores and poor to barren sandstones are very vague. The thickness of ore bodies fluctuates from 1.5 to 20 m and more. The dip angles of the ore bodies correspond to the dip angles of the host rocks and are 0-15° in the western and northwestern parts of the field, 15-35° in the central and eastern parts, sometimes more (Conclusion on mining No. 03-23-21-747 date2009, No. 03-23-21-691 date 2009, Final report for 2022).

The most stable are ore and barren gray sandstones. Siltstones, argillites and intraformational conglomerates are unstable. Argillites and siltstones cover about 40% of the ore reserves of the Annensky mine. A decrease in stability is observed in areas where folding, crushing, as well as in zones of fracturing of rocks and ores have appeared. However, the room-and-pillar mining system developed during the development of reserves at the Zhezkazgan deposits caused deterioration of the mining and geomechanical conditions in the conditions of repeated underground mining of reserves of the Annensky district mine of collapsed deposits with the periodic nature of technogenic-geomechanical processes of deformation and destruction of the abandoned pillars in the cleaning panels of the deposit block, taking into account the exit of the collapse zone to the daylight surface and the trough of deposit displacement, due to the events that occurred at PO Zhezkazgantsvetmet TOO Kazakhmys Corporation with the following events (Eremenko at al, 2016, Imansakipova at al, 2020): 6 mass collapses occurred from 1977 to 1990; from 1991-2005 the number of collapses increased by 11, where the remaining reserves in 7151 pillars - 14.5% had a service life of more than 30% and 1457 (20.4%) pillars were classified as weakened, and 123 (17.2%) were classified as destroyed; according to the results of the destruction of the MCC in the periods of 2004-2006, where there were failures between the layers in the worked-out overlapping inclined deposits in the Annensky mining region, a large collapse occurred with a combined displacement trough, covered an area of about 2 km along the strike of the deposit and along the dip, in 2015, at the Annenskaya mine of the VZhR, a collapse occurred in the form of peeling off the roof of block 29yug of the Ann-9-I-V deposit of the 160m horizon, the area of rock peeling from the roof was 9404 m² with a volume of quenched voids of 103.1 m³, in addition, according to 2015 data, for the entire period of development of the Zhezkazgan deposit, about 50 thousand MCCs were formed, which are the main reasons for the deterioration of the geomechanical situation at the deposit and the share of stable pillars decreased from 75% to 61% due to a 2-fold increase in the share of completely destroyed pillars, i.e. from 13% to 26%, and also over the course of 6 years at the Zhezkazgan deposit, the total volume of voids formed was 389,812 thousand m³;

On October 9, 2020, another local collapse occurred on the ore field of the East Zhezkazgan mine along the adit 26 deposit Kr. 9-II-III, where the collapse boundary appeared with an outlet to the day surface without seismic manifestation of rock pressure in this section of the mine and, at the same time, the collapse area was 140 x 100 m²:

Based on the above, when developing reserves of deposits in inclined deposits of the Annensky ore field of the Zhezkazgan deposit, complex mining and technical areas arise at the centers of mass collapses with a trough of displacement of the rock mass (Information on the survey from 1-31.10.2014).

Despite all the advantages, the main disadvantages of the chamber-pillar system are significant ore losses from 30% to 40%, as well as the accumulated volumes of voids, which lead to complications in the technology of cleaning excavation, self-collapse of pillars (Figure 1) and chamber roofs.

For Zhezkazgan field the total area of the excavated space collapsed and at the stage of irreversible deformation processes is about 48% of the total area of the excavated space, the share of targets with a long period of existence.

*Materials and methods.* On the flanks of the developed part of the Zhezkazgan deposit, the reserves of the Annensky ore field are concentrated, where the main ore mining is currently concentrated, located to a depth of 500 m on deposits with an angle of inclination from 15° to 35° and more degrees. At the same time, more than 80% of the reserves are also concentrated in overlapping deposits. The number of overlaps in some cases reaches 5-7 or more (Conclusion on mining No. 04-3.1.4-9-204 dated 11.07.2019, No. 03-23-21-747, dated 2009).

Compared to the central ore field, the rocks of this region have steeper dip angles of up to 30° ÷ 35° or more. The dip angles of flexures reach 70°. Deposits with dip angles of 0 ÷ 15° make up about 12% of the ore reserves and are located in the western and northwestern parts of the region. In the central part of the region, deposits with dip angles of 15° ÷ 35° contain about 80% and in the eastern part (dip angle over 35°) – 8% of the reserves.

a b

**Figure 1.** Process of ICC destruction: a – initial view, b – after 30 years of condition

*Note – Figure from the final report for mining operations at the Annensky mine sites No. 03-25-1366 dated 26 December 2009*

The excavation of the tselik from the open worked-out space requires strict compliance with the technology of excavating the MCC in a stable worked-out space and their safety margin of at least with constant monitoring of the condition of the worked-out space using a regional radio telemetry system for monitoring seismic events in real time.

The authors carried out a study of collapses that occurred at the Annensky mine in 2004-2006, which showed that the shear process is complicated by shearing of rocks along inclined surfaces of the massif weakening. The observed shears occur along inclined interlayer contacts, cracks and slip mirrors, which were formed in the process of formation of flexural zones: interlayer movements occurred in flexural zones during bending of the layered rock strata. Sliding mirrors with friction furrows and clay were formed along them. The directions of movements and furrows on the sliding mirrors are crosswise to the strike of the flexural zones. Shear voids were later filled with vein minerals of calcite type. Calcite filler of shear cracks is well detected in workings, in the roof of chambers during visual inspections. Its strength is significantly lower than that of even red-coloured rocks.

The observed shifts are a vivid manifestation of the massif destruction along the inclined weakening surfaces, on which the condition of special limit equilibrium is realised (according to the terminology of Acad. Sokolovsky V.V.):

$$\tau_{np} = C' + \sigma \cdot tg\varphi' \quad (1)$$

where $\tau_{np}$, σ – ultimate tangential and normal stresses on weakening surfaces; $C'$, $\varphi'$ – adhesion and friction angle on the same.

On inclined weakening surfaces with an angle of incidence *a, the* effective normal *s* and tangential stresses *t are* found according to the formulae (Figure 2):

$$\sigma = \gamma H(\cos^2\alpha + \lambda \cdot \sin^2\alpha)$$

$$\tau = 0{,}5(1-\lambda)\gamma H \cdot \sin 2\alpha \quad (2)$$

The displacement along the weakening surfaces will occur when the acting tangential stresses (1) exceed the limiting stresses (2).

According to the measurement results, the maximum natural stresses $_{s1}$ act horizontally along the strike of flexures, practically along the dip of the layers and weakening surfaces, and are 2 times higher than the vertical gravitational pressure of the overlying strata $\gamma H$. Therefore, in calculations for the conditions of the Annensky mine it is necessary to take $\lambda = 2$.

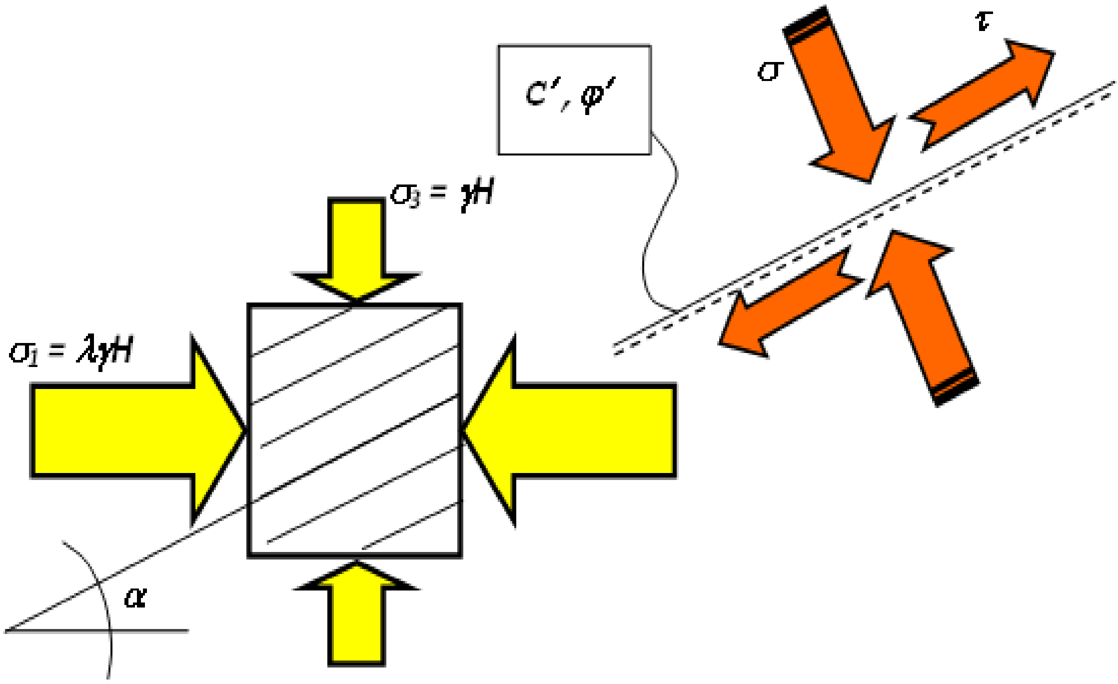


**Figure 2**. Scheme for calculation of acting stresses on weakening surfaces

*Note – Figure from the final report for mining operations at the Annensky mine sites No. 03-25-1366 dated 26 December 2009*

According to the calculation results, the actual distribution of loads on the MCC inside the panels is uneven: the central rows of the MCC, which are furthest from the BC, are loaded more than the outermost rows (Figure 3) The distribution of loads on the MCC has the form of a vault (Final report for 2022).

On the flanks of the developed part of the Zhezkazgan deposit are concentrated reserves of the Annensky ore field, where the main ore extraction is now concentrated, placed to a depth of 500 m on deposits with an inclination angle of 15° to 35° and more degrees. Therefore, we consider the different process blocks separately below.

*1. Technological block*. Block 15-15 south of the Ann-5-I deposit is located between the horizons -35m – 55m, and the deposit of these blocks Ann-4-I is located between the horizons – 46m – 96m.

From the conducted studies, there is the first access to this block along the delivery drift of the block - Block 10 bis Ann-5-I from the drift 6 of the horizon -100 m-105 m, and the second access is along the drift of block 7 bis of the horizon -90 m.

The minimum rock layer between deposits 5-1 and 4-1 is 20 m, which will allow the underlying deposit 4-1 to be developed without losses in the future.

*2. Technological block.* Block 15 of the Ann-3-II, Ann-3-I deposit is located between the horizons -62 m and -135 m and is shown in Figure 2, below it is the Ann-4-I deposit, access to these deposits is available.

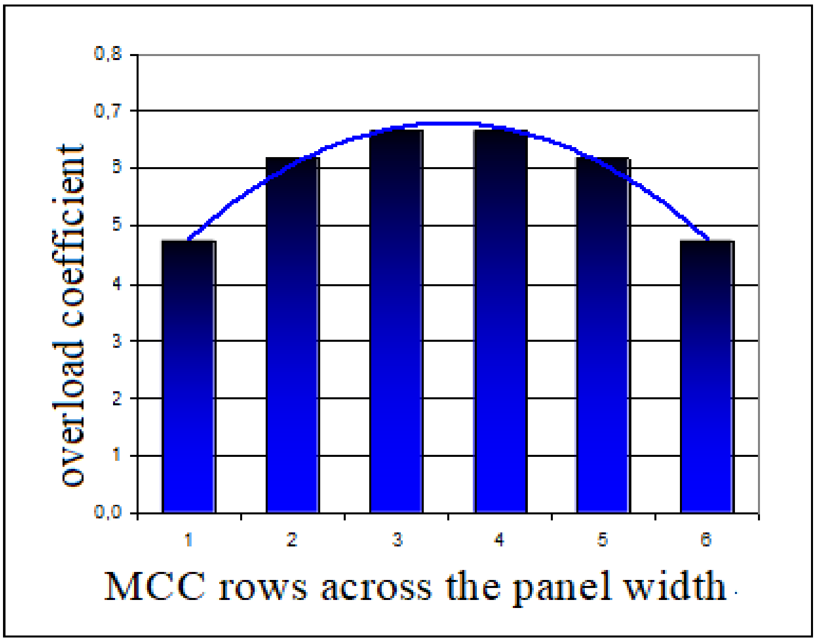


**Figure 3.** Distribution of MCC row loads in the panel

*Note – Figure from the final report for mining operations at the Annensky mine sites No. 03-25-1366 dated 26 December 2009)*

To develop the reserves in this block, we first compare the elevation marks of these blocks of the horizon -62 m -135 m and then, taking into account the elevation marks, we determine the available access to them for driving workings at the horizon -105 m -90 m.

*3 Technological scheme of blocks.* Bl.22-23-24 of the deposit Ann-3-II, 3-I are located between the horizons +12 m and -18 m and the deposit Ann -2-IV is located below (Fig. 3).

For repeated development of reserves from the MCC for this block, the following technological schemes are available:

– the first access to the block is via the transport drift of the Block 29 Vostok horizon -47m;

– the second access is via the drift 1 horizon -90m;

– there is access to the Ann-2-IV deposit via the entrance 2 horizon -60m.

Since the transport drift of the Block 29 Vostok horizon -47m approaches the elevation marks of the Ann-3-II, 3-I deposits of the +12 m horizon and the -18m horizon, it will be possible to pass the transport slope from it upward to the +12m horizon. After the transport slope reaches the required mark from top to bottom along the dip of the deposit, it will be necessary to pass the field delivery drift and simultaneously develop the Ann-3-II, 3-I deposits in a descending order according to the local project for their development.

And the Ann - 2-IV deposit will be developed after the development of the deposit reserves from the upper horizons. For this, it is necessary to pass to them from the entrance of the 2nd horizon -60 m transport drift and the development of its reserves will be carried out from top to bottom according to a similar scheme.

*4. Block 7 bis of the Ann-2-II* deposit is located on the horizon 0 m of the Annenskaya mine of the VZhR (Fig. 5) and there is access to it, where a field drift is being carried out along the delivery drift of block 7 bis, from north to south, and from it we will produce preparatory mine workings. For this, the development of the reserves of this block must be carried out from top to bottom in accordance with the Local Project for their development.

*5. Technological block Bl.* 89bis of the Ann-7-I deposit is located between the horizons +57m +20m and has access along the adit 2 of the horizon -90m and access along the adit 6 of the horizon -90m.

Below this block there is a collapsed deposit Ann-3-II of the horizon -62 m and horizon – 135 m. Based on this, access to this block is closed and is not subject to repeated development of their ore reserves. In this connection, it is necessary to restore previously completed mining and development workings to study this area. For this purpose, when developing reserves from the MCC from the collapse zone with a displacement trough in hazardous areas, all mining operations must be carried out in strict compliance with the requirements of geomechanical safety, seismic safety, industrial safety and other regulatory requirements for safe operation.

Thus, from the above, all analyzed blocks have access for repeated field development of the remaining reserves at the Annenskaya mine of the VZhR, except for the technological block Bl. 89bis of the Ann-7-I deposit.

*Results and their discussions.* Based on the results of technical and economic calculations for the above-mentioned 5 blocks of the Annenskaya VZhR mine, the calculation of the production cost per 1 ton of cathode copper for the blocks is as follows: Block 15-15 south of the Ann 5-I deposit - 4621 S/t, Block 15 of the Ann 3-II deposit - 4653 S/t, Block 22-23-24 of the Ann 3-II and 3-I deposits - 6002 S/t, Block 54 of the Ann 3-II and 2-IV deposits - 8104 S/t, Block 7bis - 9052 S/t.

Development of the remaining reserves and extraction of copper cathode at the Annenskaya mine in the blocks: Block 15-15 south of the Ann-5-I-4-I deposit; Block 22-23-24 deposits Ann-3-II, 3- I v. and, 2-IV; Block. 54 deposits Ann-3- II, 2-IV; Block. 7 bis deposits Ann-2- II, Block. 15 deposits Ann-3- II, 3-I v. n., located in a collapsed zone with seismic activity in the conditions of a displacement trough, must be carried out in descending order. First of all, block 54 is involved in development, then block 22-23-24, then blocks 15 and 15-15 south, in places where there are no overlapping deposits and then block 7bis. In order to predict the expansion of the displacement trough boundary, in area and depth in the area of the collapse of the Annenskaya mine, VZhR, as well as to study the negative impact of the displacement trough development in the collapse zone on mine workings and stoping space, we recommend conducting systematic deformation monitoring, consisting of instrumental observations and research work in the field of geomechanics, studying the SSS of the massif.

No negative impact of the deformation processes of the displacement trough on mine capital workings, such as the shafts of the Annenskaya mine, VZhR, the conveyor drift, which is located at the -180 m mark, was revealed.

*Conclusion.* Based on the study of the stages and order of development of reserves (reserve depletion) with the assessment of the possibility of developing the remaining reserves and extracting the MCC, as well as Block 15-15 south of the Ann deposit - 5-I-4-I; Block 22-23-24 deposits Ann-3-II, 3-I v.n., 2-IV; Block. 54 deposits Ann-3-II, 2-IV; Block. 89 bis deposits Ann-7-I, Block. 7bis deposits Ann-2-II, Block. 15 deposits Ann-3-II, 3-I v.n. are located in the seismic activity zone, where the following results were obtained:

1. The conducted assessment shows the possibility of re-development of the remaining ore reserves from the MCC with field preparation at the Annenskaya mine in the blocks: Block. 15-15 south deposits Ann-5-I-4-I; Block. 22-23-24 deposits Ann-3-II, 3- I v. I, 2-IV; Block. 54 deposits Ann-3- II, 2-IV; Block. 89 bis deposits Ann -7-I, Block 7 bis deposits Ann-2- II, Block

15 deposits Ann-3- II, 3-I centuries B.C., located in a collapsed zone with seismic activity in the conditions of the displacement trough of deposits of the Annenskaya VZhR mine;

2. No negative impact of the deformation processes of the displacement trough on the capital workings was revealed, such as the shafts of the Annenskaya mine, VZhR, the conveyor drift, which is located at the -180 m mark;

3. Based on the conditions for ensuring the safe conduct of mining operations, the order and sequence of involving reserves in the development of the remaining ore reserves from the MCC at the Annenskaya mine in the considered blocks were determined: Block 15- 15 south of the Ann-5-I-4-I deposit; Block 22-23-24 deposits Ann-3-II, 3- I v. i, 2-IV; Block. 54 deposits Ann-3- II, 2-IV; Block. 7 bis deposits Ann-2- II, Block. 15 deposits Ann-3- II, 3-I v. n., located in a collapsed zone with seismic activity in the conditions of a displacement trough and must be carried out in descending order. First of all - development of block 54, then block 22-23-24, then blocks 15 and 15-15 south, in places where there are no overlapping deposits and then block 7bis;

4. Based on the results of the technical and economic calculation, involvement in the development of reserves of Block. 15- 15 south of the Ann-5-I-4-I deposit, 15 of the Ann-3-II, 3-I deposit, Blocks 22-23-24 of the Ann-3-II, 3-I deposit are characterized by positive economic efficiency at a cathode copper price of 8141 $/t, and for blocks Block 54 of the Ann-3-II, 2-IV and 7 bis of the Ann-2-II deposit, the efficiency is ensured at a cathode copper price of 11800 $/t.

*Conflict of interest.* The author(s) declare that there is no conflict of interest.

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References

Lushnikov V.N., Sendi M.P., Eremenko V.A., Kovalenko A.A., Ivanov I.A. Gornyy zhurnal. 2013. – No 12. – Pp. 11-16. 2. Kelly B. Stress analysis for boreholes on department of defense lands in the western United States: A study in stress heterogeneity. Proceedings, Thirty-Eighth Workshop on Geothermal Reservoir Engineering. Stanford University, Stanford, California, February 11-13. 2013. – Pp. 139-150.

Neverov A.A, Konurin A.I., Shaposhnik Yu.N., Neverov S.A, Shaposhnik S.N. Geomechanical substantiation of sublevel-chamber system of developing with consolidating stowing. 16th International Multidisciplinary Scientific Geoconference, SGEM 2016: science and technologies in geology, exploration and mining, vol. II, jun. 30-jul. 06, 2016. Albena, Bulgaria. – P. 443-450.

Eremenko V.A., Neguritsa D.L. Efficient and active monitoring of stresses and strains in rock masses. Eurasian Mining. 2016. – No 1 (25). – P. 21-24.

Eremenko A.A., Mel'nichenko V.F., Bashkov V.I., Gakhova L.N. Vestnik Kuzbasskogo gosudarstvennogo tekhnicheskogo universiteta, 2015. – No 6. – Pp. 25-32.

Freydin A.M., Neverov S.A., Neverov A.A., Konurin A.I. Fundamental'nye i prikladnye voprosy gornykh nauk. 2017. – Vol. 4. – No. 3. – Pp. 180-185. 8. Ordin A.A., Nikol'skiy A.M., Metel'kov A.A., S

Imansakipova, B.B., Sdvyzhkova, O.O., Isabayev, K.Z., Shakieva, G. The combined method for assessing risk factors in underground construction /Naukovyi Visnyk Natsionalnoho Hirnychoho Universytetu, 2020(3), R. 53–58 https://doi.org/10.33 271/nvngu/2020-3/053 (Q3, Precentile 57%, CiteScore 1.9)

Xu C, Zhou KP, Xiong X, Gao F, Lu Y. Prediction of mining induced subsidence by sparrow search algorithm with extreme gradient boosting and TOPSIS method. Acta Geotech 2023:1–17.

Zhou J, Zhu SL, Qiu YG, Armaghani DJ, Zhou AN, Yong WX. Predicting tunnel squeezing using support vector machine optimized by whale optimization algorithm. Acta Geotech 2022;17(4): – Pp. 43-66.

Tishkov, M “Evaluation of caving as a mining method for the Udachnaya underground diamond mine project”, in Y. Potvin & J. Jakubec (eds), Proceedings of the Fourth International Symposium on Block and Sublevel Caving, Australian Center for Geomechanics, Perth, 2018, pp. 835-846

Couto PM, Green S. Improving the Mining Efficiencies Utilising a Combination of Elongates and Packs at Unisel Mine. Welkom: AMMSA On-line Publication; 2018. p. 1–12.

Bekbergenov D.K. Features of the technology of repeated ore mining in the conditions of a collapsed area by the underground method on the example of the Zhezkazgan deposit. // Mining information and analytical bulletin (scientific and technical journal). 2017. - No. 3 (special issue 3). - 16 p.
Analysis of the possibility of developing reserves of the Annenskaya and 57 mines, located in the displacement trough. No. 04-3.1.4-9-52 dated 16.10.19. Geomechanical department of the Mine surveying + geomechanical service of the Mining Administration of the MMC TOO "Kazakhmys Corporation". - 8 p. 12.
Information on the survey of mine workings falling within the displacement trough and 150 m, the zone of the displacement troughs of 2004-2006. Along the Annenskaya mine, the VZhR from 1-31.10.2014 – 12 p.
Assessment of the involvement of upper horizon blocks in re-development adjacent to the displacement trough from the east (block 25 Ann. 8-II horizon 270 m, block 6 Ann. 7-II-I horizon 170 m, block 26 Ann. 6-II horizon 230 m). No. 04-3.1.4-9-204 dated 11.07.2019. PO Zhezkazgangtsvetmet Geomechanical Department of Kazakhmys Corporation LLP. – 9 p.
Conclusion on mining operations adjacent to the sections of the Annensky mine that collapsed in 2004 (block 3-3bis Ann-2-II-I. block 7 Ann-2-IV. Block 31 Ann-2-II-I, block 12 bis Ann-3-II), No. 03-23-21-747 dated July 21, 2009. According to Zhezkazgantsvetmet Mining and Geomechanical Department. – 2 p.
Conclusion on the conduct of mining operations at the sites of the Annensky mine in the 150-meter zone adjacent to the 2004 displacement trough (Block 6 Ann. 7-I, block 11-south Ann. 3-Iv, block 25-south Ann. 8-II, block 4-south Ann. 4-II-I), No. 03-23-21-691 dated June 25, 2009. PO Zhezkazgantsvetmet Mining and Geomechanical Department, Branch of Kazakhmys Corporation LLP. – 3 p.
Conclusion on conducting mining operations in the vicinity of the Annensky mine sections that collapsed in 2004 (GPR block 12 bay Ann-3-II, block 11 south bay Ann-2-IV). No. 03-23-21-1331 dated December 14, 2009. Mining and Geomechanical Department, Mine Surveying and Geomechanical Department of Kazakhmys Corporation. – 2 p.
Geomechanical conclusion on conducting mining operations in the Annensky mine sections in the displacement trough and adjacent to it. No. 03-25-1366 dated December 26, 2009. Mining and Geomechanical Department, Mine Surveying and Geomechanical Department of Kazakhmys Corporation. – 5 p.
Final report for 2022 on the research topic "Study of compliance of the determination of parameters and the mining system in the conditions of the Annenskaya mine of the East Zhezkazgan mine" (stage 2). Project Manager Bekbergenov D.K., KazNIITsvetmet LLP. Almaty, 2022. – 347 p.

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